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ARE ROOTS AEROTROPIC?[1]

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(WITH FIVE FIGURES)

I. HISTORICAL REVIEW.

AFTER noting the peculiar curvings and contortions that roots of *Zea Mays* exhibited when growing in water, especially when their tips were just touching the surface of the water or were slightly immersed, Molisch[2] formulated the hypothesis that these roots were affected by a poverty of oxygen in their immediate vicinity, and through their curvings were brought into a richer supply of that gas. In pursuance of that thought, he sought to determine whether roots of other seedlings would not also show definite responses to the influence of various gases. In determining this point, Molisch employed only one form of apparatus, which is here described.

The chamber containing the gas to be used was a wide-necked bottle, closed with a plate of hard rubber in which were cut one or two slits 2^{cm} high by 1.5 to 2^{mm} wide. A strip of cork was fastened to the neck of the bottle in such a position that the seedlings, when pinned to it, were supported in front of and very close to the slits. The bottle was laid, with the slits in a vertical position, on a glazed dish, and was covered with a large bell jar lined with moist filter paper. Light was excluded.

[1] LXVIII Contribution from the Botanical Laboratory of the University of Michigan.

[2] MOLISCH: Ueber die Ablenkung der Wurzeln von ihrer normalen Wachsthumsrichtung durch Gase (Aerotropismus). Sitzungsber. Akad. Wiss. Wien **90**: III. 1885.

The roots of *Pisum sativum* and *Zea Mays* were subjected to the application of various gases diffusing or streaming in mass from the slits, and the reactions of the roots were termed aerotropic. Only those responses to the application of oxygen, hydrogen, carbon dioxid, and nitrogen are considered in my paper, as the other gases used by Molisch were poisonous, and might produce chemotropic or traumatropic reactions.

The striking similarity in the results of Molisch's experiments —namely, that regardless of the species of seedling or the gas used, whether it were a stream of pure oxygen, of oxygen of a lower pressure than the normal, of nitrogen, or of carbon dioxid, the majority of the roots in every case made an initial curve toward the source of the gas and later turned away—looks suspicious. His own explanation of these phenomena is that the curves both toward and away from the gas chamber were due to the presence of an optimum pressure of the gas for longitudinal growth. If this were true, it would seem to make the response simply a mechanical one.

Several features of Molisch's work are subject to criticism. To thrust needles through the cotyledons, as he did, is objectionable for several reasons. To take seedlings directly from the sawdust and support them before the slits is objectionable, since injurious substances often occurring in sawdust effect curvatures in roots, which do not show until some time after the seedlings have been set up. The gases which streamed out of the slits were not moist, except in the experiments with CO_2 and possibly pure oxygen. This condition would tend to bring about hydrotropic curves. Too few seedlings were used to establish certain conclusions. The data of the experiments lack details as to growth of seedlings, degree of curvature, and other minor points. Lastly, the position of the root at the conclusion of the experiment is accepted for record, regardless of the numerous curves, positive and negative, which this root made during the continuance of the experiment. Since the paper by Molisch nothing on this subject has appeared.

The present investigation of the supposed aerotropism of roots was conducted in the Botanical Laboratory of the University

of Michigan during the years 1900–1902, under the supervision of Professor Frederick C. Newcombe, to whose valuable suggestions and constant assistance is largely due whatever of merit this paper may possess. It is with pleasure that I here acknowledge my indebtedness to him.

II. EXPERIMENTAL INVESTIGATION.

It has been my purpose to determine the following points as definitely as possible: whether roots are aerotropic under natural conditions; and whether they are aerotropic under any conditions. Observations have been made of the effect of oxygen, hydrogen, carbon dioxid, and, as a test, illuminating gas, these being allowed to flow against one side of roots in gaseous form or dissolved in gelatin blocks. This is the same as the effect of a less and a greater pressure of oxygen than the normal atmospheric pressure.

1. With roots in water.

In the series of experiments under this head, the seedlings were grown in filtered tap-water and placed parallel to one chamber, or between two chambers of gas, which usually had a parchment membrane closure.

At the outset several methods of experimentation were employed to determine whether roots of *Zea Mays* grow straight in water if supplied with a larger proportion of oxygen than usual. In one series, seedlings having roots from 10 to 15 ^{cm} in length were secured to the sides of inverted air chambers, without membranes, immersed in the water, the kernels of corn being above water, and the root tips just below the lower edge of the chamber. The root tips were thus from 5 to 10 ^{mm} from the air in the immersed chamber, but 9 ^{cm} or more from the air above the water in the larger chamber. Observations showed that of 20 seedlings used, 7 turned toward the air in the immersed chamber, 4 away, 3 in other directions, and 6 remained straight.

In another series, seedlings supported, as in all the following experiments when necessary, between two strips of moist blotting paper held firmly to small pine rods by rubber bands between the seedlings, were suspended over a chamber which was connected

with a gasometer of oxygen, and had a finely perforated membrane closing the upper end through which the oxygen was allowed to bubble slowly up toward the roots. The root tips were kept not more than 5 mm from the membrane. Of 87 seedlings thus supported, only 14 grew even approximately straight.

In a third method, seedlings were supported in a Novy jar containing filtered water saturated with oxygen under an atmosphere of pure oxygen. After the water had been saturated, the

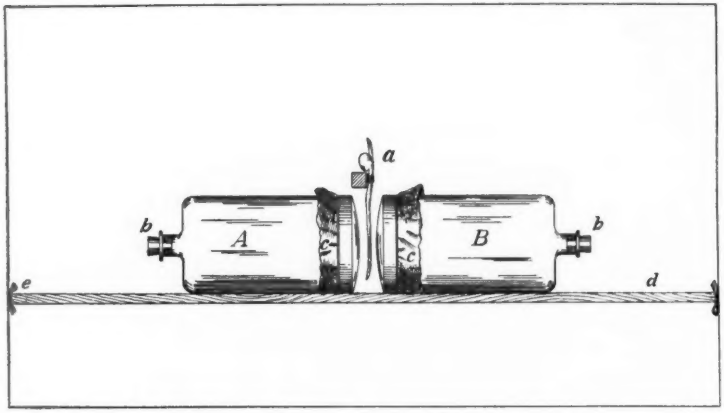

FIG. 1.—*A*, chamber containing air; *B*, chamber containing CO_2; *a*, seedling supported on wooden bar; *b*, rubber stopper; *c*, parchment membrane; *d*, strip of pine; *e*, small piece of rubber tubing.

cover was slightly lifted to avoid confining the stems in an atmosphere of pure oxygen. Every four hours the seedlings were transferred to another Novy jar of water saturated with the same gas. A control experiment was prepared with the same number of seedlings in ordinary filtered tap-water. There was no apparent difference in the behavior of the roots in two preparations. Of 25 seedlings used in the first preparation, 7 only were growing straight at the close of the thirteenth hour.

Evidently, from these experiments no proofs have been found to justify Molisch's hypothesis that roots of *Zea Mays* in their curving in water are turning from a position in which the water is poor in oxygen to a position in which it is richer in that gas.

We must seek farther for the cause of the curving of these roots when growing in a water medium.

Other seedlings were grown in water, and placed parallel to membranes of immersed gas chambers, as shown in *fig. 1*. In the first series of experiments only one gas chamber was used, and this contained air. An explanation of the following table, in which are recorded the results, will suffice for most of the other tables found in this paper. The plus sign (+) indicates a curvature toward the supply of oxygen, and the minus sign (−) a curvature away. Only those roots which turned and continued thereafter growing toward the air chamber are counted as positive. The reverse of this rule is used in determining the negative curves. Under the zero sign (0) are classified all other curves and roots growing straight. It is noted that of 362 seedlings, including those of corn, radish, popcorn, and pumpkin, nearly as many turned away from the supply of oxygen, or the air chamber, as toward it, and more than half (206) were neutral. The angles of curvature were slight.

TABLE I.

(Plus sign indicates curve toward higher proportion of oxygen.)

Species	No. of individuals	Period: hours	Temperature of water	+	−	0	Angle
Zea Mays (field corn)	86	22–24	22–29°	24	12	50	10–45°
Raphanus sativus...	104	24–96	....	33	15	56	10–45°
Zea Mays (popcorn)	120	20–24	20–30°	18	36	66	5–90°
Cucurbita Pepo	52	20–24	16–29°	9	9	34	5–60°
Totals	362			84	72	206	

In the second series of experiments the pressure of carbon dioxid was increased above the normal on one side of the root by saturating the water frequently with that gas or by passing a slow stream of CO_2 continuously through the water, other conditions being the same as in the preceding experiment. It might be expected that the roots would turn from the CO_2 toward the supply of oxygen in the air chamber. The following table seems to indicate faintly such a response, where 39 radish seedlings were positive, as opposed to 24 that were negative or indefinite.

TABLE II.

(Plus sign indicates curve toward higher proportion of oxygen.)

Species	No. of individuals	Period: hours	Temperature of water	Initial length of root in cm.	Saturation with carbon dioxid	+	−	o
Raphanus sativus	10	48–120	20°	3–4	Once	6	1	3
Raphanus sativus	19	72	20°	3–4	Several times	11	7	1
Raphanus sativus	34	14–20	20°	3–4	Continuous stream	22	5	7
Totals	63					39	13	11

These seemingly aerotropic curvatures are invalidated, however, by those of another experiment, tabulated below, in which 166 seedlings of *Cucurbita Pepo*, *Raphanus sativus*, and *Zea Mays*, placed parallel to gas chambers containing CO_2, and a mixture of CO_2 and air (as in *fig. 1*), gave only 37 curves away from the source of CO_2 as opposed to 129 that were either turned toward that gas or were neutral. That the majority of the curves in the two experiments were in opposite directions relative to the position of similar gases indicates that the curves were not aerotropic.

TABLE III.

(Plus sign indicates curve away from gas chamber.)

Species	No. of individuals	Period: hours	Temperature of water	Initial length of root in cm.	In chambers		+	−	o	Angle
					% CO_2	% air				
Cucurbita Pepo ..	29	24–48	25°	2–7	100	..	4	2	23	5–45°
Raphanus sativus.	40	20–30	....	1–6	100	..	5	6	29	5–45°
Zea Mays.....	44	9–22	24–31°	1–6	100	..	9	8	27	5–45°
Zea Mays	45	18–23	21–25°	1–7	75	25	17	6	22	5–60°
Zea Mays	8	5.5	25°	2–5	50	50	2	..	6	5–45°
Totals.....	166						37	22	107	

In a series of experiments following these, similarly prepared, with the root tips not more than 2 to 5 mm from each membrane, the results could not be interpreted as showing aerotropism, since of 135 seedlings of lupine and radish, 46 turned toward the supply of oxygen, 39 away, and 50 were neither positive nor negative.

Finally, to increase the difference in the oxygen pressure on opposite sides of the roots as much as possible, the water in which the roots were supported opposite a chamber of air was prevented, by the device illustrated in *fig. 2*, from replenishing its supply of oxygen which was exhausted through respiration. A small aquarium was chosen which was hermetically sealed by weighting down a glass cover (*F*) on a cushion of rubber (*E*) cemented securely to the upper edges of the aquarium. The chamber (*B*)

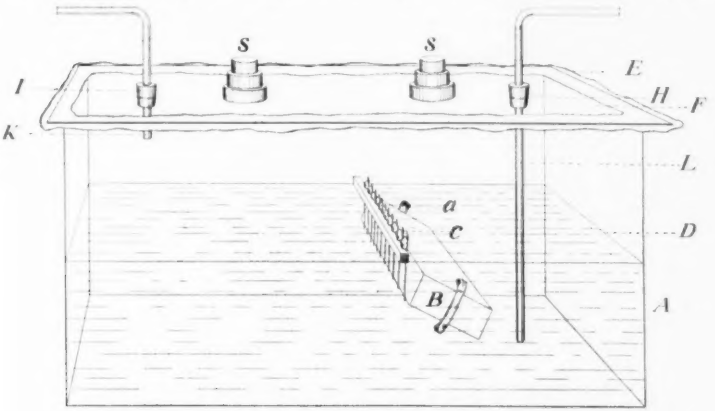

FIG. 2.—*A*, aquarium; *B*, chamber containing gas; *C*, seedlings; *D*, height of water; *E*, rubber cushion; *F*, glass cover; *H*, aperture in cover; *I*, rubber stopper; *K*, glass tube through which gas enters; *L*, glass tube for escape of water; *S*, weights; *a*, rubber tubing.

containing air was a rectanglar glass dish, 14 cm by 8 cm by 4 cm, supported, at angles between 20 and 45° to the horizontal, by pressing in small pieces of rubber tubing (*a*) between the ends of the dish and the sides of the aquarium. No membrane was used to inclose the gas. When the required seedlings (*C*), which had been growing in a vertical position in a damp chamber from 12 to 24 hours, were supported before the air chamber so that their tips extended 1 to 3 mm below the upper edge of the chamber and 1 to 5 mm away from it, the aquarium, already partly filled, was now completely filled with water, the cover pressed down, and the water above the roots replaced through tube *L* by gas

brought in through tube *K*. In such a contrivance the oxygen pressure in the water, which was reduced through respiration, would be continually renewed on the side facing the air chamber.

Table IV shows no aerotropic curves with the 54 seedlings of *Cucurbita Pepo*, 40 of which were neutral, while the remaining 14 were divided equally between positive and negative. The angles of curvature were not large and the growth was slight at first, due to insufficient pressure of oxygen. However, as more and more oxygen diffused from the chamber the roots grew more rapidly.

TABLE IV.

(Plus sign indicates curve toward air chamber.)

Species	No. of individuals	Period: hours	Temperature of water	Initial length of root in cm.	Gas above water		+	−	o	Angle	Growth
					% CO_2	% air					
Cucurbita Pepo.	16	10	27°	3-9	10	90	2	4	10	5-45°	Little first 6 hrs.
Cucurbita Pepo.	18	10	28	3-9	30	70	3	2	13	5-45°	Little first 6 hrs.
Cucurbita Pepo.	20	22	27	1-3	60	40	2	1	17	5-20°	Little first 4 hrs.
Totals.....	54						7	7	40		

When the water above the gas chambers was replaced by mixtures of hydrogen and air in varying percentages, approximately the same results were obtained both in curvature and growth, as shown in Table V.

TABLE V.

(Plus sign indicates curve toward air chamber.)

Species	No. of individuals	Period: hours	Temperature of water	Initial length of root in cm.	Gas above water		+	−	o	Angle	Growth
					% H	% air					
Zea Mays (popcorn) ..	18	7	25°	3-9	10	90	..	2	16	5-30°	Good growth
Cucurbita Pepo	18	12	30	2-4	25	75	2	1	15	5-90	Considerably retard'd
Cucurbita Pepo	18	10	25	2-4	$33\frac{1}{3}$	$66\frac{2}{3}$	..	4	14	5-20°	Slight during first 6 or 7 hrs.
Zea Mays (popcorn) ..	19	21	25	3-5	50	50	3	2	14	10-60	Not apparently retarded
Zea Mays (popcorn) ..	16	22	..	....	75	25	4	2	10	.....	Slight during first 5 hrs.
Totals.....	89						9	11	69		

The duration of the experiments was necessarily short, since the roots could not be readjusted to the air chamber without altering the conditions. It is noticeable that of the 143 seedlings thus tested, 16 turned toward the air chamber, 18 away, and 109 were not responsive. The angles were generally very slight.

In the foregoing series of experiments, in which the roots were immersed in water with the oxygen pressure so reduced as to retard growth beyond the usual retardation in water, the pres-

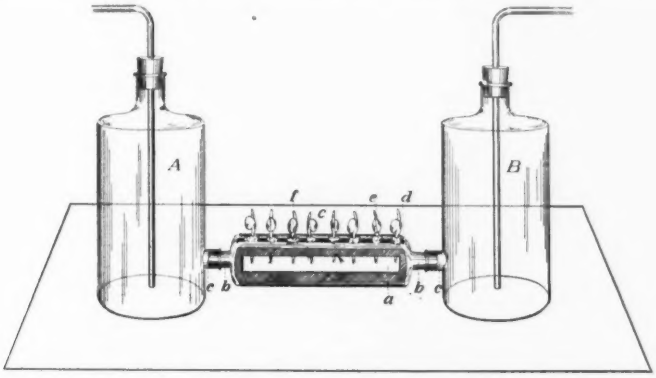

FIG. 3.—*A*, chamber filled with various gases; *B*, chamber containing air; *C*, chamber connecting *A* and *B*; *a*, glass side-wall of chamber *C*; *b*, cork sealed in end of chamber *C*; *c*, opening into bottle; *d*, position of groove; *e*, seedlings; *f*, cotton around seedlings.

ence of air within a few millimeters of the root tips induced no aerotropic curves.

2. *With roots in damp chambers.*

Because of the slow diffusion of gases in water, other results were anticipated on growing seedlings in damp chambers. To this end an apparatus (*fig. 3*) was constructed consisting of two eight-liter bottles (*A* and *B*) which were connected near their bases by a rectangular chamber (*C*) whose inner dimensions were 15^{cm} by 3^{cm} by 1^{cm}. This chamber was covered entirely with plaster of Paris, except along the sides, where the plaster was removed to expose the inner side walls of glass (*a*). A large cork (*b*) was sealed into each end of the chamber, through which

openings were made of the same cross-section as the chamber. The distal end of each cork was fitted tightly into the opening of the bottles (*A* and *B*). On the upper side of the plaster case was hollowed out a groove (*d*), and perforations were made through the floor of this groove in such a way that the roots of the seedlings (*e*) projecting through these holes would be suspended in a chamber of gas when *A* and *B* were filled with gas. The groove made a good support for the cotyledons and for the cotton which was wrapped around them to keep them moist. The plaster was entirely covered with a thin layer of paraffin. In this way an air-tight passage was made from one bottle to another. To insure a moist condition of the gases which filled chambers *A* and *B*, several sheets of damp filter paper were placed in the bottles, and the cotton around the seedlings was moistened frequently. Besides this, the connecting chamber was soaked in water to infiltrate the plaster before inserting the seedlings.

In such a contrivance, judging from a preliminary experiment, it was thought that the gases diffused too rapidly through the chamber to be effective. However, by testing with a mixture of illuminating gas and air in one bottle and air in the other, and observing the contortions in the roots produced by the illuminating gas, it seemed evident that the gases must diffuse slowly enough to allow a considerable difference in the gases on the opposite sides of the roots.

Seedlings of *Zea Mays*, *Lupinus albus*, *Vicia sativa*, and *Pisum sativum* were now supported in the chamber, and bottle *A*, filled with 100 per cent. CO_2 or with mixtures of air and CO_2 in varying percentages, and bottle *B* filled with air. It was found that when a mixture of 20 per cent. CO_2 and 80 per cent. air on one side was opposed to air on the other, of 18 seedlings used only 1 was positive toward the air, the remaining being indefinite; while when 100 per cent. CO_2 was opposed to air, of 18 seedlings only 2 were positive and 16 indefinite. In the former case the roots grew 5 to 10^{mm} during the experiment, while in the latter case only 0.5 to 1.5^{mm}.

Although probably there was not a very great difference in the composition of the gases on the opposite sides of the roots,

there was unquestionably some difference; and, notwithstanding this, it may be seen that the roots, although influenced in growth, did not make any definite curves with references to these gases, even when 100 per cent. CO_2 was used. In nature one can hardly conceive of conditions which would give a greater difference in the composition of gases on opposite sides of the roots.

3. With roots in earth.

In the lower half of a battery jar was fastened securely with sealing wax a glass plate in a vertical position so that gas could not pass the septum. Water was placed in the bottom to the depth of 2 or 3^{cm}, and pieces of broken plant crock were thrown in loosely. A glass tube was brought down to the bottom of each chamber, with its lower end curved upward under a piece of broken crock. The whole jar was now filled with moist earth. The seedlings were planted in a line directly above the upper edge of the glass partition. A different gas was led into each chamber, having passed on its way from the gasometer through liter bottles of water, that the rate of flow might be known and kept the same for each gas.

In this experiment the roots were in practically natural conditions, except for the gases used. If they were sensitive to the gases, and responded by curving toward one or the other, then aerotropism would be demonstrated.

At first, very short seedlings were used and the gases allowed to diffuse slowly through the earth; but later, longer roots were used and the gases passed in more rapidly. In every case CO_2 was passed into one side of the chamber and air into the other, the volume of each varying from 18 to 40 liters during the experiment of 24 hours' duration. Of the 165 seedlings of *Raphanus sativus*, 31 were positive toward the air, 34 negative, and 100 were neither positive nor negative, 98 of the last being straight. In the last two sets, when the 60 seedlings were planted twelve hours before the gases were led into the chambers, the majority of the roots were straight at the close of the experiment.

In a modified form of this experiment the seedlings were planted in a vertical layer of earth or sawdust 18^{cm} long by 12^{cm}

wide by 1 cm thick, inclosed in an iron wire gauze cage which was fitted in as a partition so closely between the sides of a glass jar that gases brought into the two chambers thus formed could pass over only through the earth or sawdust. This chamber was carefully covered; the seedlings were kept constantly moist; and the CO_2, or mixture of CO_2 and air, on one side, and air on the other, were forced in from a gasometer or water stream air-pump at the same rate and equally moist. By such a method there was certain to be an access to different gases on opposite sides of the roots.

Regardless of the percentages of CO_2 used, the results were not indicative of aerotropism; 14 roots bent toward the earth through which air was flowing, 14 away, and 28 grew in the vertical plane. *Pisum sativum*, *Lupinus albus*, and *Zea Mays* (popcorn) were used in this experiment.

From these two methods of experimentation it is seen that, while 221 representative seedlings were exposed to the one-sided application of a normal pressure of oxygen as opposed to some mixture of gases having a less pressure of oxygen or none at all, and while they were otherwise in almost natural conditions, still only 45 turned toward the source of oxygen, while 48 turned away, and 128 remained neutral. Certainly no one would contend that such results indicate that the roots are aerotropic, though they do show some disturbance in the direction of growth.

4. With roots in gelatin.

In the use of gelatin a medium was found that would permit of growth of the root, while preventing a rapid diffusion of gases. Solutions of 6 or 7 per cent. of gelatin in distilled water were thoroughly saturated, when cold but before solidifying, with air, hydrogen, or CO_2, either by forcing the gas through the solution, or with the solution in an air-tight chamber by exhausting and refilling the chamber with the gas which passed through the gelatin as it entered. These solutions were allowed to harden for twelve hours, standing in chambers of air, or hydrogen, or CO_2, as the case might be, in paper-lined, rectangular dishes, 20 cm by 12 cm by 4 cm, into which they had been poured when

saturated, the gelatin containing the hydrogen, or CO_2, remaining in the air-tight chamber of that gas from which it had not been removed at any time during the operation.

Two of these blocks of hardened gelatin (*fig. 4*, *e* and *e*), removed from the rectangular molds and freed of all unnecessary paper, were transferred quickly to a damp chamber (*A*), lined with moist filter paper dipping into several centimeters of water (*D*) in the bottom of the jar. The gelatin blocks were placed on their narrow sides on a raised platform of glass (*C*) supported in the bottom of the jar, so that their broad sides were vertical and facing each other. Seedlings, supported in the usual manner on the bar of wood, were now quickly placed between the blocks of gelatin, the latter were pressed together and held firmly in the vertical position by means of glass plates (*a* and *a*) and wooden bars (*d* and *d*), at their backs, the latter pressing at both ends against the sides of the damp chamber.

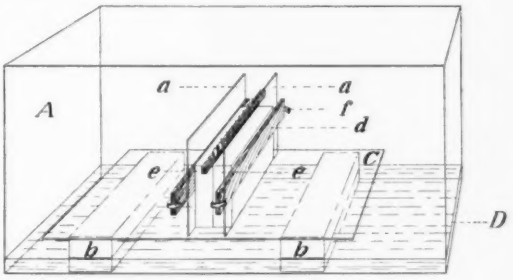

FIG. 4.—*A*, damp chamber; *D*, height of water; *C*, glass plate resting on *b*; *b*, glass jar; *e*, block of gelatin; *a*, supporting glass plate; *d*, supporting wooden bar; *f*, rubber tubing.

It may be seen from Table VI that in the first two sets of seedlings the gelatin was not thoroughly saturated with CO_2. Under such circumstances the difference in oxygen pressure on opposite sides was not great, and the seedlings had ready access to a sufficient oxygen pressure for good growth, but made no definite curves. In the other sets, in which the gelatin was thoroughly saturated with CO_2 or hydrogen, the oxygen pressure was not sufficient for good growth. Here again none of these roots showed curvatures of any definite character.

A still further trial, however, was made by supporting the roots in a very thin septum of gelatin and allowing gases to diffuse through the gelatin from the opposite sides.

TABLE VI.

(Plus sign indicates growth into gelatin containing air.)

Species	No. of ind'vs	Period: hours	Gases		+	−	o	Growth in mm.	Remarks
Lupinus albus..	15	24	CO_2	Air	5	3	7	....	Gelatin not thoroughly saturated with CO_2.
Lupinus albus..	18	30	CO_2	Air	2	11	5	....	Gelatin not thoroughly saturated with CO_2.
Lupinus albus..	16	24	CO_2	Air	6	7	3		
Lupinus albus..	13	30	CO_2	Air	5	7	1		
Lupinus albus..	7	30	CO_2	Air	..	..	7	20	
Zea Mays..... (popcorn)	11	30	CO_2	Air	2	3	6	8–28 12–27	Growth retarded during first 30 hrs.
Pisum sativum.	5	48	H	Air	1	..	8	4–20	Growth much retarded.
Lupinus albus..	4	60		Air				8–17	

A frame (*fig. 5*) was made of strips of glass cemented together along the edges and fastened at the ends in grooves in wooden bars (*a* and *e*). These strips were of two sizes. The wider ones (*b*) were so secured in the wood that narrow spaces were left between them (*c*), which were covered by the narrower strips (*d*), except in the lower 1.5 cm. Thus a series of little chambers was formed not more than 3 mm in diameter, open at the top and closed at the bottom except for the opening (*f*) between the strips of glass. By temporarily closing these openings with strips of glass the chambers could be filled with gelatin, after the hardening of which the two strips of glass could be removed. This frame with the little chambers filled with gelatin was now pressed down into a battery jar containing enough water to cover the lower bars of wood (*h*). By inserting rubber tubing between the edges of the frame and the sides of the battery jar two almost air-tight chambers were formed.

Down the middle of each column of gelatin a needle was thrust to make easy the passage of roots which were pushed down into the gelatin till the tips came below the glass covers, as shown in *fig. 5*. The chambers on the two sides of the partition were then filled with gas as desired.

In one series of experiments, in which CO_2 was passed slowly into one chamber and air more rapidly into the other, of 3 lupine, 5 pea, and 4 popcorn seedlings used, all grew nearly straight, though 2 took a somewhat slanting course toward the air chamber.

In another series, in order to reduce the surface for the cross-

diffusion of the gases, the gelatin was smeared over with olive oil and the surface opposite the roots melted off with a hot needle. Thus, just as far as possible, the cross-diffusion of gases was confined to the vicinity of the root-tips, and the tips were exposed to the gases, except for the very thin covering. Air and CO_2 were introduced on opposite sides of the seedlings, and

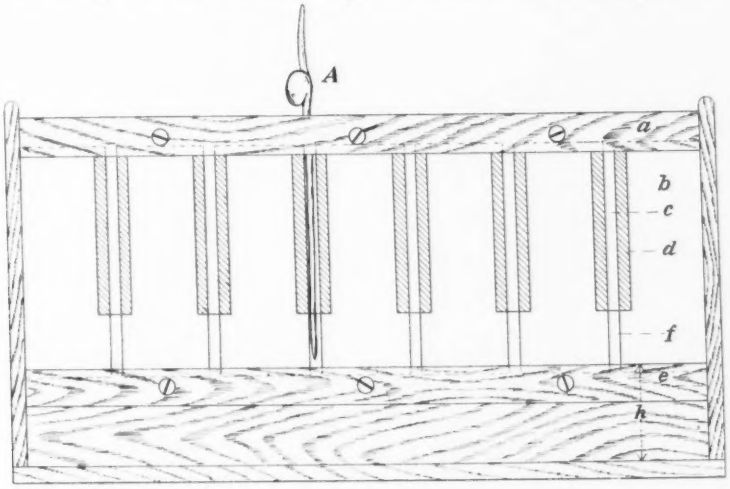

FIG. 5.—*A*, seedling; *a* and *e*, bars of wood; *b*, wide strips of glass; *c*, narrow spaces; *d*, narrow strips of glass sealed on; *h*, height of water; *f*, spaces filled with gelatin.

at the close of 42 hours it was found that, while there had been very little growth, there had been no curves.

Thinking to determine roughly the rapidity of diffusion of gases in such contrivances as have been described above, one block of gelatin, made alkaline and colored with phenophthalein, was opposed to one saturated with CO_2, and the septum of gelatin in *fig.* 5 was made pale red and the CO_2 and air brought on opposite sides as in the experiment. In the former case, within 4 hours the gelatin was decolorized to a depth of 10^{mm} and in 24 hours the entire block had lost the red color; while in the preparation shown in *fig.* 5 the gelatin was entirely decolorized in 1¾ hours. Judging from these two tests, the CO_2 must

have diffused rapidly enough through the gelatin to cause curves had the roots been aerotropic; and if CO_2 diffuses rapidly, hydrogen and air would diffuse even more rapidly.

Beyond doubt, in these experiments with the gelatin cultures, and especially in the last-described series, the roots have been met on opposite sides by different gases, and if they were aerotropic have been given the opportunity to show such reaction. In spite of this, under all these conditions the majority of the roots have remained straight, and the main result has been simply retardation of growth due to the diminished oxygen pressure. It is certainly difficult to conceive of any more favorable conditions under which the roots might have been placed to exhibit aerotropism.

5. Experiments similar to those of Molisch.

There remains only one more task, namely to determine if possible the cause of the curves which Molisch observed and termed aerotropic. To this end an apparatus was made similar to that used by him and described in the first part of this paper. It consisted of a rectangular jar containing folds of moist filter paper, having an opening on one side through which moist gases were led from a gasometer; and having a plate of cork infiltrated with paraffin sealed into the open end. In the plate were cut six vertical slits 2^{cm} long by 1 to 2^{mm} in width, and fastened to the upper edge of the closure was a ledge of cork in which was cut a longitudinal slit 5^{mm} wide. Small corks, through which projected the roots held firmly in their support with moist cotton, rested upon this ledge so that the roots passing through the slit in the ledge hung directly before, and within 2 to 4^{mm} of the slits in the cork plate closing the gas chamber.

An apparatus prepared in this way was placed in a large covered aquarium lined with and also containing many folds of moist filter paper supported on wooden bars, so as to add to the evaporating surface. The aquarium was covered with opaque black paper and the whole wrapped in black cloth. The gas, led in through an opening in the cover of the aquarium from the gasometer, was passed through a wash bottle containing water

to insure a moist condition of the gas as well as to aid in determining the rate of flow.

In these experiments, pea, radish, and popcorn seedlings were used, and in the gas chamber were CO_2, hydrogen, or air. When CO_2 was diffusing from the gas chamber during 6 to 12 hours, and 17 seedlings were used, it was found that 4 were curved away from the source of CO_2, 5 toward it, and 8 were neutral; 4 of those which turned toward the gas chamber grew into the chamber through the slits.

When hydrogen was diffusing from the chamber, 7 of the 12 seedlings used curved toward the source of that gas. At the close of 12 hours it was found that there had been good growth, and that 4 roots had grown through the slits into the hydrogen chamber.

When air was diffusing through the slits in the cork plate, 10 of the 18 seedlings turned toward the air chamber, 1 away, and 7 were neutral.

The gas chamber was thoroughly aerated after each series of experiments, so that no remnant of the gas previously used could influence the results.

The most interesting results were obtained, however, when no special gas was used, but only air at rest both inside and outside the small chamber. It was found that under these conditions also curvatures were made, 4 of the six seedlings turning toward the small chamber containing air.

Altogether in this series of experiments, in which 53 seedlings were used, regardless of the gases diffusing from the chamber, 26 turned toward the gas chamber and 11 away, while 16 remained neutral. Even more striking was the observation that curves appeared in the roots whether or not a gas was passed through the slits. It must be very evident from these observations that such curvatures are not aerotropic, but are to be accounted for in some other way. It seemed not unreasonable to conclude that they were hydrotropic curves, and that, as the large chamber was probably not thoroughly saturated with moisture, the roots were turning toward the moisture emanating from the surface of the cork plate.

To verify this conclusion, a preparation was made in which the roots were placed between two cork plates set in the same damp-chamber, with the same evaporating surface as before.

Six pea seedlings were set up in the ordinary manner, the roots being 2 to 3^{mm} from each cork plate. After 2 hours, 1 root was touching one plate of cork; after 3 hours, 4 were touching this plate; and at the end of 24 hours, 2 roots were touching one cork, 2 the other, 1 was straight, and 1 had grown out beyond the two plates.

The evidence was absolutely convincing that here were purely hydrotropic curves. The cork surfaces had acted as evaporating surfaces in a chamber of the kind ordinarily said to be saturated with moisture. Accordingly it is highly probable that Molisch's damp-chamber, which had relatively less evaporating surface than mine, was not saturated with moisture and that the curves he obtained were hydrotropic rather than aerotropic.

III. DEDUCTIONS FROM EXPERIMENTS.

In my experiments, roots of *Zea Mays*, *Pisum sativum*, *Raphanus sativus*, *Cucurbita Pepo*, and *Lupinus albus* have been subjected to the one-sided access of oxygen, hydrogen, and carbon dioxid, to determine whether these roots do really curve toward or away from these gases in natural or artificial conditions.

Incidentally I have offered my solution for the curvatures of roots recorded by Molisch and by him termed aerotropic.

1. When the roots of the various seedlings mentioned in this paper were grown in water between submerged chambers, the one containing air and the other CO_2 or H, no constant and regular curvatures were observed. Under these conditions the majority of the roots were indifferent to the influence of any of these gases. The same results followed when the roots were not submerged in water, but placed between the gas chambers in a larger damp-chamber.

2. When the seedlings were grown in a thin, vertical layer of earth, forming a septum between air and CO_2, or air and hydrogen, or in earth permeated on one side with air and on the other with CO_2 or hydrogen, very few curves were formed, the large

majority of roots growing straight or, if curved, the curves were not directed by the presence of the gases.

3. When the roots of seedlings were grown in a thin layer of gelatin, between different gases, as air and CO_2 or air and hydrogen, or when grown between and enclosed by blocks of gelatin, one saturated with air and the other with CO_2 or hydrogen, no curves of constant direction were shown.

4. The preparation of experiments similar to those of Molisch, where roots were supported close to narrow slits opening into gas chambers from which gases were constantly diffusing, brought to light the important truth that curves were produced, generally toward the gas chambers, no matter whether gases (oxygen, hydrogen, or CO_2) were diffusing from the chambers, or no gases whatever were diffusing and a like pressure of air surrounded the roots on all sides. The observations led to the discovery that these curves were purely hydrotropic.

5. Finally, from a careful consideration of the results of experiments set forth in this paper, with the large number of individuals of representative species, and the variety of methods of experimentation employed, both under nearly natural and under artificial conditions, one is driven to the conclusion that, at least so far as the representative land plants here used are concerned, definite direction curvatures are not induced in roots by the one-sided access of such gases as oxygen, hydrogen, or carbon dioxid, and their roots are therefore not aerotropic.

Thus far the evidence is decidedly against a belief in the aerotropism of roots.

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CONTRIBUTIONS FROM THE ROCKY MOUNTAIN HERBARIUM. V.

AVEN NELSON.

TO THOSE who have known them in the field and who have studied them carefully in the herbarium, desert plants are of peculiar interest. No other plants show so many adaptations to their environment and, as a consequence, so many variant characters that have become fixed. During the spring of 1902 Mr. Leslie N. Goodding, a student in the University of Wyoming, was sent into the field in the interest of the Rocky Mountain Herbarium. He made collections in southern Nevada, southern Utah, the Wasatch Mountains, and in the Uintah Mountains, especially on their southern desert slopes. He secured many rare species of great interest, as well as some novelties. This paper is based, in a large measure, upon his field work.

NEW GENERA AMONG THE APLOPAPPUS SEGREGATES.

Notwithstanding the attention that the genus *Aplopappus* Cass. has had in recent years, it seems that further division would tend to simplicity. The genus Stenotus as now constituted is nearly homogeneous. Before the recent separation of two of the species and their erection into the genus Stenotopsis by Rydberg (Bull. Torr. Bot. Club **27**: 617), a concise generic description was unthinkable. My attention was called to this fact recently when some material of *Stenotus interior* (Coville) Greene came into my hands for determination. To one perfectly familiar with the normal species, the possibility that this plant also was listed as a Stenotus did not for some time occur to me. Several other genera come to mind more readily than this, among them Macronema, when one has in hand only the leafy floriferous twigs that constitute the usual herbarium specimens.

The difficulties encountered in generically placing the original species of the group (*Aplopappus linearifolius* DC.) has been recognized from DeCandolle down. Greene has stated the

whole matter very fully in the fifth of that series of papers entitled "Observations on the Compositae" (Erythea **2**: 71). In his discussion of the asteroid genera (Erythea **2**: 53) it seems to me that he was at his best, and gave us a bit of botanical philosophy that must stand for all time. But the criterion there laid down, and now generally accepted, as marking the limits of genera, confirms Stenotopsis as a valid genus. Into this genus another species must therefore find its way as follows:

Stenotopsis McLeanii, n. n.—*Aplopappus McLeanii* T. S. Brandegee, Bot. Gaz. **27**: 448. 1899; *Stenotus McLeanii* Heller, Muhlenbergia **1**: 7. 1900.

There are three other plants that seem to me to form an equally good and homogeneous group. One of these, starting as *Stenotus pygmaeus* (T. & G. Fl.), passed into Aplopappus (Gray Syn. Fl.) and was there associated with a near relative, *Aplopappus Lyallii* Gray. Greene in his discussion of the segregates of Aplopappus (Erythea **2**:) considers the status of the former of these two and decides that it has enough Macronema characters to justify its transfer to that genus. Recently, however, it has been distributed on Greene's determination as Stenotus (Pl. Baker, 1899), though this may have been a clerical error. The second of these species Greene either overlooked or ignored entirely. But now Rydberg (Mem. N. Y. Bot. Gard. **1**: 382. 1900) after due consideration very reluctantly makes the second *Pyrrocoma Lyalli*. Henderson, apparently not accepting the segregates of Aplopappus, describes (Bull. Torr. Bot. Club **27**: 347. 1900) a third species which he pronounces "close to *A. Lyallii* as well as to *A. pygmaeus*." With these doubts and these differences of opinion staring us in the face, why not again accept the criterion laid down by Greene (that is, if I interpret him aright, a genus may be founded on characters of habit, along with characters of the vegetative organs and morphological characters of the flower, but not upon morphological characters of the flowers alone in the face of differences in habit and of the vegetative organs) for the limitation of genera, and thus bring together under one name these species which are allied by habit and morphological characters to each other and are aberrant in any recognized genus or genera in which they can be placed.

Tonestus, n. gen.—Low herbaceous perennials from woody roots, having a short more or less branched subligneous caudex. Stems simple, a few to several centimeters high, leafy throughout, monocephalous. Leaves herbaceous, obscurely 3-nerved, spatulately tapering to a short margined petiole. Heads relatively large (15–25^{mm} broad); the involucral bracts herbaceous, in about two loosely imbricated rows, usually with one to several outer foliaceous ones. Rays conspicuous, ten or more; the disk flowers more numerous. Pappus soft and white, equaling the corolla. Style tips slender, subulate-elongated. Akenes glabrous or pubescent. Anagram of Stenotus.

1. **Tonestus Lyallii,** n. n.—*Aplopappus Lyallii* Gray, Proc. Acad. Philad. **1863**: 64; Syn. Fl. **1**: 131; *Pyrrocoma Lyallii* Rydb. Mem. N. Y. Bot. Gard. **1**: 382. 1900.

2. **Tonestus laceratus**, n. n.—*Aplopappus laceratus* Henderson, Bull. Torr. Bot. Club **27**: 347. 1900; *Stenotus laceratus* Heller, Muhlenbergia **1**: 7. 1900.

3. **Tonestus pygmaeus**, n. n.—*Stenotus pygmaeus* T. & G. Fl. **2**: 237. 1842; *Aplopappus pygmaeus* Gray, Am. Jour. Sci. II. **33**: 239. 1862; *Macronema pygmaeum* Greene, Erythea **2**: 73. 1894.

STUDIES IN THE COMPOSITAE.

Coleosanthus venulosus, n. sp.—A low shrub 3^{dm} or less high, freely branched, the stems whitened with irregularly furrowed bark: leaves glabrous, sprinkled with microscopic (waxy?) particles, subsessile, triangular-deltoid, rather thin, with narrow prominent reticulate veins, the base truncate or subcordate, sharply acute or even acuminate at apex, cuspidately few-toothed on the margins, often subcrenate, generally less than 2^{cm} long, mostly on the herbaceous branchlets which terminate in slender monocephalous peduncles: heads about 14^{mm} high and fully as broad: involucral bracts minutely granular-puberulent as are also the peduncles, sub-equal, acuminate; the inner linear-lanceolate, few-nerved; the outer ovate-lanceolate, 6–10-nerved, usually with a subtending bract: flowers numerous: akenes linear, with 10 minutely hispidulous nerves: pappus strictly capillary, scarcely scabrous.

I know of no near ally of this species. It is based on Mr. Goodding's no. 678, from southern Nevada, "The Pockets," April 30, 1902; "in the crevices of the rock."

Hofmeisteria viscosa, n. sp.—Allied to *H. pleuriseta:* stems decumbent at base; lignescent below, grayish-white with glabrous bark; the upper herbaceous part granular-viscid: leaves slightly viscid, greatly reduced as to the blade; the lamina often reduced to a broadly linear-subulate point, frequently with 1 or 2 teeth near the base, from one-third to one-sixth as long as the slender petiole which is often 3^{cm} or more long: heads about 25-flowered, at the ends of the slender naked peduncles in 2–7 capitate clusters, the pedicels very short: involucral bracts oblong-linear, abruptly short-acuminate, scarious with three parallel green nerves: pappus of a few slender bristles (8–12); the squamellae wanting or if present represented by a few (1–6) variable bristles; corolla shorter than the pappus, its tube with minute scattered stipitate glands: the club-shaped styles included or at least not noticeably exserted: akene very short, ovate-oblong.

This species is somewhat at variance with the genus in the congested heads. It differs from all the species in its leaves and from its nearest ally as well as the others in floral characters.

Secured in southern Nevada, at "The Pockets," April 30, 1902, on dry stony bottom lands; no. 671.

Chrysopsis imbricata, n. sp.—Stems few to many from the crown of the root, quite simple, decumbent-ascending, $3–4^{dm}$ long, subcinerous, the pubescence short and close with some longer hirsute hairs: leaves very numerous, broadly oblong or narrowly elliptic, sessile, often broadly obtuse, abruptly apiculate, sometimes lanceolately narrowed, grayish-hirsute; usually crowded till they appear imbricated, with smaller fascicled ones in the axils, the lower wanting at anthesis; the floral leaves reduced and often ciliate: heads several, closely glomerate at the summit of the stems, $10–14^{mm}$ high: involucre cinereous-hirsute: rays several, conspicuous, distinctly nerved: pappus fuscous: akenes silky.

The writer's no. 8618, from Pike's Peak, September 1, 1901, is taken as the type. Dr. Clements's no. 39, from the same region, is this species, but

not typical in habit, having been browsed off (my set). It was distributed as *C. hispida* (Hook.) Nutt.

Chrysopsis scabrifolia, n. sp.—Stems several from a woody root, ascending or erect, dark green and subpruinose, simple, or branched above, 12–20^{cm} high: leaves small (1–2^{cm}), nearly linear, at anthesis wanting below but crowded above, greenish in aspect, but distinctly scabrous with short upturned hairs from a pustulate base: heads few, solitary at the ends of the resinous-glandular branches, about 1^{cm} high: involucral bracts in 4–5 rows, merely puberulent: rays 20 or fewer: pappus somewhat sordid, equaling the disk corollas.

The specimen upon which this species is based was secured by Mr. Paul J. White, in Woods co., Okla., June 29, 1900. It was distributed as *C. hispida*, to which it bears little resemblance and less yet to any other species known to the writer.

The Natural History Survey of Oklahoma, so energetically conducted by by Dr. Van Vleet, of the State University, has suffered the loss, by fire, of many very valuable collections, among them the plants of which these specimens were a part. Dr. Van Vleet is again in the field, and it is to be hoped that he may once more secure some of the rare species found on his first expedition.

Guttierrezia myriocephala, n. sp.—Branching freely from the shrubby base, becoming 3–5^{dm} high, the grayish branches dissolving into myriads of filiform, green, subresinous branchlets: leafless below, trichophyllous above: cymes small, supernumerous: heads many, small, nearly cylindrical, somewhat glutinous: bracts of the involucre linear, acute, in about 3 rows: rays minute, 3–4; the disk flowers as many or fewer: pappus paleae 6–8, broadly linear and subacute.

The type is no. 8645, secured near Badger, Laramie co., Wyo., in the sandy draws of the Platte Cañon, September 3, 1901.

Solidago scopulorum, n. comb.—*S. multiradiata scopulorum* Gray, Proc. Am. Acad. **17**: 187; Syn. Fl. **1**^{2}: 148.

There seems to be no reason for supposing that true *S. multiradiata* Ait. comes within the limits of the United States. The original high northern form is said to occur from Labrador and Hudson's Bay to Behring Strait and Unalaska. It is characterized by villous-pubescent stems, few and closely glomerate heads with very narrow rays. To carry the Rocky Mountain form along as a variety of this arctic species can serve no useful purpose.

Pyrrocoma brachycephala, n. sp.—*Aplopappus lanceolatus brachycephalus* Piper, n. var. in herb.—Stems several from the crown of a thickened root, slender, erect, 4–6 dm high, glabrous, rather leafy, clothed at the base with the shreds of former petioles: leaves glabrous or nearly so; the basal few, linear-oblanceolate, entire or minutely denticulate, acute at apex, 1–2 dm long, tapering to a margined petiole nearly as long; the cauline sessile, noticeably denticulate: inflorescence a long crowded or glomerate spike-like raceme, with foliar bracts: heads about 1 cm high: the bracts unequal, in about 4 rows, oblong, abruptly acute.

The above description is taken from Mr. William C. Cusick's no. 2778 (in the Rocky Mountain Herbarium), the label of which bears the legend already given. The plant is so different from *Pyrrocoma lanceolata* in its habit, in the spicate, foliar-bracted inflorescence, and in the character of its leaves that it seems best in transferring it to Pyrrocoma to give it specific rank at the same time.

Pyrrocoma Kennedyi, n. sp.—Stems several from the root, ascending, 2–4 dm high, light-green, somewhat villous-pubescent, paniculately branched upward and bearing numerous heads: leaves permanently and rather softly and densely lanate-pubescent, mostly basal, oblong or oblanceolate, acute at apex and conspicuously dentate with narrow spinulose teeth, 5–10 cm long, tapering into a petiole usually much shorter; cauline leaves smaller and narrowed to a sessile base: heads medium sized (1 cm or more broad and high), several to many (often 30 or more on each of the several stems) on the slender linear-bracted branches of the panicle: involucral bracts in 3 or 4 rows, unequal, herbaceous-tipped, but not noticeably broadened or squamose: rays mostly fewer than 20.

The nearest ally of this species is *P. lanceolata*. In fact, it bears much the same relation to this that *P. inuloides* bears to *P. uniflora*. The distinctly paniculate arrangement of the numerous heads, together with the permanent woolliness of the plant as a whole, seems to justify its separation from *P. lanceolata*.

The type is no. 630 secured by Professor P. B. Kennedy on Maggie Creek, Elko county, Nev., August 13, 1902. Similar but smaller is his no. 615, Tuscarora flats, same county. Mr. William C. Cusick's no. 2744, Oregon, 1901, distributed as *Aplopappus hirtus* Gray, var., is the same, as is also probably no. 1137 by Merrill and Wilcox, from Buffalo River, northwestern Wyoming.

Stenotus latifolius, n. sp.—Caudex woody, with numerous slender naked branches rising some centimeters above the ground; herbaceous stems numerous, slender, leafy, monocephalous, 10–15^{cm} high, striate, glabrous but obscurely glutinous: leaves glabrous, slightly glutinous, acute or apiculate, 3-nerved and more obscurely reticulate-veined; the crown leaves not persistent, small, spatulate and cuneately tapered to a petioled or subsessile base, usually not more than 7–12^{mm} long; stem leaves longer, several (5–7), the lowest broadly spatulate-cuneate, the upper from broadly oblong to lanceolate, usually with tapering base, 2–3^{cm} long; the upper one-third of the stem naked-pedunculate, often with a linear bract: heads 10–12^{mm} high: the bracts in 3–4 series, oblong, abruptly acute, light green with narrow scarious margin: rays several, rather short: pappus bristles slender, white, about as long as the somewhat angled canescent akene.

This species has no near relative, but is most nearly approached by *S. falcatus* Rydb. From this and all the other species it is at once separated by the open naked slender branches of the caudex which wholly lack the enlarged indurated and petiole-sheathed crowns of the other species. This also is the only species with decidedly foliose stems, the leaves of which are relatively much broader and more herbaceous than in the other species.

Type no. 1111, by Mr. Goodding, "rock crevices," mountain slopes, near Provo, Utah, June 16, 1902.

Sideranthus Gooddingi, n. sp.—Caudex woody, branched, several centimeters high: herbaceous stems slender, 2–3^{dm} high, numerous, fascicled, nearly simple, monocephalous or with 2–3 monocephalous branches, minutely glandular-puberulent throughout: leaves linear, spinulose-tipped, 1–3^{cm} long, 1–2^{mm} broad, with a few slender flagellate-spinulose teeth upon the margins, rarely with a few short linear lateral lobes: heads about 1^{cm} high, the disk hemispherical: involucral bracts in 5–6 series, very narrowly linear, somewhat greenish and minutely glandular, flagellate-spinulose tipped: rays orange-yellow, many, linear: disk flowers numerous: pappus bristles scabrous, of several lengths, the longest not equaling the disk corollas: akenes softly pubescent, broadly linear, not more than half as long as the disk corollas.

Allied to both *S. gracilis* (Gray) and *S. australe* (Greene) Rydb. It is

distinguished from both by the nearly simple branches, the glandulosity of the whole plant, and the narrowly linear leaves. From the former also by the greener stems which lack the canescent harsh pubescence of that species; from the latter also by a very different involucre.

I dedicate this species to Mr. L. N. Goodding, who secured a most valuable collection of plants in southern Nevada and Utah, in fact, as will be noticed, most of the species of this paper. No. 667, from "rock crevices," "The Pockets," southern Nevada, April 30, 1902.

Townsendia dejecta, n. sp.—Depressed-acaulescent, the caudex bearing a few heads in a small rosulate semisubterranean tuft: leaves linear-spatulate or oblanceolate, somewhat petioled, 1–2^{cm} long (including the petiole), surpassing the heads, somewhat fleshy, green and apparently glabrous but under a lens appressed strigose on both faces: heads sessile at the base of the leaves, about 1^{cm} high; involucral bracts in 2–3 series, oblong ovate, mostly subacute, purple or some with green centers, ciliate margined, otherwise nearly glabrous: rays white or possibly purple: disk flowers numerous, the corolla lobes purple: pappus white, similar in disk and ray flowers as are also the akenes: akenes brown, flattened, spatulate-cuneate, about 4^{mm} long, wholly glabrous except for some obscure puberulence at the very base, as long as the pappus and disk corolla.

Most nearly allied to *T. alpigena* Piper, from which it may be distinguished by its absolute stemlessness, the strigose pubescence, the purple of the involucre, of the disk, and probably of the ray, and by the glabrous akenes wholly devoid of bidentate hairs. Townsendias with glabrous akenes are rather rare.

Collected by Mr. Goodding in the Uintah Mountains, near Dyer's Mine, at an altitude of about 3,000^{m}. Type no. 1238, July 3, 1902.

Machaeranthera verna, n. sp.—Perennial from thickened woody roots: stems several from the ligneous crown, erect, branched above, 4–6^{dm} high, striate, nearly or quite glabrous except above: leaves from linear to lanceolate, glabrous or sparsely crisped or ciliate-pubescent especially on the margins, spinously few-toothed on the margins; the uppermost reduced and bract-like, lanately-puberulent as are also the branchlets: heads corymbose-paniculate: involucre 12–14^{mm} high and broad; its bracts imbricated in 5–6 rows, scarcely viscidulous, lightly sublanate, linear acuminate, the slender tip green and at length reflexed: rays purple,

rather numerous: pappus slightly dingy, equaling the slender corollas: akenes linear, pale, sparsely and minutely soft pubescent.

This tall handsome species differs from the species known to the writer in its early development. It comes into blossom in April, whereas most of the species are autumnal or at least of late summer. But apart from that its morphological characters readily distinguish it.

Collected by Mr. Leslie N. Goodding, Big Bend, Virgin River, Arizona, May 10, 1902, no. 757.

Machaeranthera coronopifolia, n. n.—*Dieteria coronopifolia* Nutt. Trans. Am. Phil. Soc. **7**: 300. Annual, or probably often biennial, divaricate-branched from the base upward (rarely two or more stems from the base), 1–2^{dm} high, green but puberulent and minutely glandular: leaves from moderately to very deeply pinnatifid, oblanceolate in outline, from 1–4^{cm} long; the segments very variable, from linear to oblong or merely with broad teeth upon the margins of the blade, setulose-mucronate: heads large: the involucre in about 5 series, the slender green reflexed portion of the bract about as long as the scarious imbricated base: rays often nearly 2^{cm} long, bluish-purple: akenes sparingly appressed pubescent.

This is in part the *Aster tanacetifolius* of Gray, Syn. Fl. 206; not *Machaeranthera tanacetifolia* Nees, nor the *M. tanacetifolia* of Greene in Pitt. **3**: 59.

This northern species may at once be distinguished from that southern and earlier named one by its greener aspect, lower stouter and more spreading habit, simply pinnate leaves, broader and more numerous involucral bracts, and by the sparse appressed pubescence of the akenes. Of the southern species I have seen only a few plants, but Wooton's no. 22, Mesilla, N. M., seems to be quite typical. The northern species is frequently collected in Wyoming, northern Colorado, and western Nebraska.

My numbers are 443, Platte River, July 13, 1894; 2581, Chug Creek, August 1, 1896; and 8205, Colorado-Wyoming line, August 28, 1900.

Aster meritus, n. sp.—Stems one to several from each of the many crowns of the woody roots and rootstocks that make up the dense perennial base, the tufted stems suberect or more usually widely spreading and forming a mat 5–10^{dm} across, 2–4^{dm} long, green but under a lens sparsely pubescent, simple or branched, leafy throughout: leaves oblong or sometimes elliptic, 3–7^{cm} long, subacute, entire or obscurely crenulate-serrate, glab-

rous above, often sparingly and minutely ciliolate-scabrous below and on the margins: heads several to numerous, usually in a crowded corymbose leafy cyme, turbinate-campanulate: involucral bracts broadly linear, in 3–4 rows, subacute or obtuse, erect, purple-tipped and margined, delicately ciliate, sometimes puberulent (as are the peduncles and pedicels): rays mostly fewer than 15, purple or violet, pappus brownish: akene linear, half as long as the pappus, minutely ciliate and obscurely few-nerved (about 5).

The literature of the subject seems to indicate the distinctness of the Aster occurring in the middle Rocky Mountains, which has been called *A. Sibiricus* or *A. Richardsonii*. There can be no doubt that the true *A. Sibiricus* L. is foreign to North America and that it belongs where its name would indicate.

It is equally clear that *A. Richardsonii* is the name given to the *A. montanus* of Nuttall. Hooker (Fl. Bor. Am. 2:7) seems to have satisfied himself that *A. salsuginosus* (?) Less. equals *A. Espenbergensis* Nees, and that the latter is undoubtedly the *A. montanus* of Rich. It follows, therefore, that the more southern form, if distinct from *A. Richardsonii* Spreng. (re-characterized by Hooker, *l. c.*), has so far remained unnamed. The original *A. Richardsonii* is a plant of the "barren country from lat. 64° to the Arctic Seas." The Torrey and Gray *Flora*, which took into consideration these arctic forms only, emphasizes the characters which separate them from the species now proposed, viz., the tomentum, the serrate leaves, the squarrose involucre, many-ribbed achenia, etc. In the *Syn. Fl.* Dr. Gray modifies this description so as to include all the European as well as the North American forms.

Typical of the species now proposed are the writer's collections as follows: Yellowstone Park, 1899, nos. 6754 and 6610 (distr. as *A. Sibiricus*); Big Horn Mountains, nos. 2334 and 7924, secured in 1896 and 1901 respectively.

Aster incertus, n. sp.—Low, more or less cespitose-tufted, from small woody root-crowns and slender rhizomes: stems leafy, usually decumbent at base, rarely more than 1^{dm} high (occasionally nearly 2^{dm}), sparingly cinereous-pubescent: leaves oblong to oblanceolate, $2–5^{cm}$ long, most of them tapering to a short petiole, glabrous or nearly so; the uppermost sessile by a clasping base: heads solitary at the ends of the stems which are usually simple, rather large and showy ($2–3^{cm}$ broad): involucral bracts spatulate, subacute, minutely soft-pubescent on the margin, otherwise glabrous and green or sometimes purple margined: rays purple, rather numerous (25–50): pappus brownish, twice as long as the brownish nearly glabrous akene.

The species here proposed seems to belong in the *A. adscendens* group. In habitat and aspect, however, it reminds one more of *Erigeron glacialis*. After trying for some time to find in the recognized Rocky Mountain species a near ally, I now offer it, with some hesitancy as a new species. The type is no. 7924, from alpine summits in the Medicine Bow Mountains, Albany co., Wyo., August 2, 1900.

Xylorrhiza scopulorum, n. sp.—A low shrub 3–4^{dm} high, the woody base branched and naked: branches with a glistening white bark, glabrous except for a tuft of wool at the old leaf-scars: young branches herbaceous, greenish, leafy throughout, sparsely lanate and above viscid-glandular, monocephalous: leaves oblong-lanceolate, green and herbaceous, lightly lanate-pubescent and glandular-dotted, spinulose-dentate, the lower short-petioled, the uppermost reduced to lanceolate bracts: heads with the expanded rays about 4^{cm} broad: involucral bracts many, linear-acuminate, about 1^{cm} long, minutely viscid-pubescent: rays numerous, white or light-blue, 3-toothed: disk flowers very numerous, slender-tubular, about 5^{mm} long, and four times as long as the short-cylindrical merely canescent akenes; pappus as long as the disk corollas.

This species is to be distinguished from *X. tortifolia* (T. & G.) Greene, its nearest ally, by its less rigid, wholly herbaceous, not at all contorted leaves, which are not in the least incised (only bordered with small spinulose teeth); by the presence of some viscid-glandulosity upon leaves, young stems, and involucre; by the leafiness of the peduncles; and by the color of the rays. Type specimens from rocky cliffs at "The Pockets," southern Nevada, April 30, 1902, by Mr. Goodding, no. 669.

Erigeron glacialis, n. comb.—*Aster glacialis* Nutt. Trans. Am. Phil. Soc. **7**: 291; T. & G. Fl. **2**: 155; *Erigeron salsuginosus glacialis* Gray, Syn. Fl. **1**^{2}: 209.

I think we shall do well to allow Nuttall's conception of the rank of this plant to stand.

Erigeron nauseosus, n. comb.—*E. caespitosus nauseosus* Jones, Proc. Cal. Acad. Sci. II. **5**: 696.

The specimens distributed by Mr. Jones (no. 5586) bear out nicely the fairly complete description cited.

Hymenoclea fasciculata, n. sp.—Stems shrubby, several to many, spreading, simple, leafless, striate, with light yellowish-

green resiniferous bark, 2–4^{dm} high; branches fasciculate or brush-like at the top of the stems, 5–15^{cm} long, glabrous or subresinous, sometimes leafless and having a spinescent appearance: leaves narrowly linear, 1–4^{cm} long, entire or with a few widely divaricate linear lobes, slightly involute, leaving exposed a median line of canescent pubescence: sterile heads small, 3–4^{mm} in diameter, about 20-flowered, mostly spicate on the ends of the branches, or more scattered and intra-axillary: their involucre green, glabrate, its lobes 7, ovate, obtuse or subacute, often ciliate-laciniate; the corollas tubular-funnelform, 2–2.5^{mm} long, distinctly surpassed by the stamens and protruded penicillate stigma, its five tooth-like lobes with a long delicate pubescence partly concealing the numerous minute glands: anthers linear, shorter than the slender filament; chaff spatulate with a long narrow claw: fertile involucre oval, 5–6^{mm} long, its scales consisting of 3 or 4 cordate-deltoid green ciliate-margined bracts and about 12 spirally arranged scales which are broadly reniform, delicately nerved, thin, and petaloid in appearance, closely enwrapping the gland-dotted coriaceous body of the involucre: akene (immature) light yellow or greenish, closely dotted with brown.

The nearest ally is *H. salsola* T. & G. Pl. Fendl. 79; Pl. Frem. 14, *pl. 8*; but the fertile involucre is only the size of the involucre in *H. monogyra* Gray Pl. Fend. *l. c.*, and its scales, like the scales of that species, are reniform and not contracted at base. Besides the many other minor differences, the two species differ markedly in habitat and time of flowering. *H. salsola* is a plant of the saline basins of desert regions of California and comes into blossom in August, while *H. fasciculata* occurs on rocky ledges and comes into blossom in April.

The type is no. 662, by Leslie N. Goodding, Kernan, southern Nevada, April 29, 1902.

Gymnolomia nevadensis, n. sp.—Perennial from slender subvertical rootstocks, from the crown or crowns of which spring few to several slender stems: stems 3–5^{dm} high, somewhat striate, sparsely pubescent with minute appressed or sometimes spreading hairs, simple or more rarely branched; the branches very slender, alternate or opposite: leaves mostly opposite, narrowly linear, tapering at both ends, 3–7^{cm} long, 1–3^{mm} wide (rarely nearly 5), appressed minutely hispid-pubescent, the margins

revolute; often a fascicle of small leaves in the axils representing the suppressed branches: heads mostly solitary at the ends of the peduncle-like branches, the main axis usually with 3; the peduncles naked or bracteate: involucre canescent, about 1 cm broad, its bracts in two series: rays 8–12, oblong to elliptic: disk corollas tubular, noticeably dilated just above the very short glandular pubescent tube: pappus wholly wanting.

Notwithstanding the morphological similarity of the floral characters of this and *G. multiflora* Benth. & Hook., the distinctness of the two can scarcely be questioned. In the excellent revision of the genus by Robinson and Greenman (Proc. Bost. Soc. Nat. Hist. **29**: 87–104. 1899) mention is made of narrow-leaved forms of *G. multiflora* which occur to the southwest of the range of the species, but judging from the specimens cited nothing like the plant now described was at hand. In any case, the species now proposed is strongly marked by its slender, rhizome-like roots, its very narrow revolute leaves, and its slender fascicled stems; in contrast with the woody taproot, the relatively stout branched stems, the lanceolate leaves, and the somewhat larger heads and broader rays of *G. multiflora*.

The type is no. 968, Leslie N. Goodding, Meadow Valley Wash, southern Nevada, May 17, 1902; in blossom and with mature akenes; growing among the rocks on dry steep mountain slopes.

Encelia virginensis, n. sp.— Perennial, the base shrubby and freely branched, 3–5 dm high including the herbaceous part of the plant: the ligneous stems white, rather slender; the herbaceous branches leafy below, terminating in a long slender monocephalous peduncle, light green, roughish-puberulent as are also the ligneous stems for a time: leaves opposite below but alternate upward, short-petioled, broadly rhomboid- or deltoid-ovate, rarely sub-cordate, generally 3-nerved from the base, 12–20 mm long, some nearly as broad: the pubescence of two kinds, some short white strigose-hispid hairs, and a fine close puberulence: peduncles 1–2 dm long, naked or 1- or 2-bracted near the head: involucre strigose-canescent; its bracts acute, in about 2 series, linear-lanceolate, rather coriaceous, some of them abruptly narrowed to a slender somewhat recurved tip: rays 12–20, minutely pubescent below, cuneate-oblong, deeply 3- or 4-toothed at the truncate apex, neutral, 15–20 mm long: disk-flowers numerous; the tube proper narrow, half as long as the cylindrical throat: style branches acute, linear: akene flattened, broadly linear-spatu-

late, slightly depressed at summit, glabrous on the sides, densely long ciliate-villous on margins and summit, about 4 mm long, as long as the corolla; pappus wholly wanting: receptacle flat; the chaffy bracts broadly linear, membranous with herbaceous tips and midrib which are finely pubescent and viscid-glandular, as are also the involucral bracts and to some extent the peduncles.

Related to *Encelia frutescens* Gray, but wholly distinct from that as originally defined in Bot. Mex. Bound. 89 (*Simsia* [*Geraea*] *frutescens*). We must consider Colonel Emory's plants from the Gila country as the type of that species. The species now defined may be represented in some herbaria under the name *E. frutescens* by specimens from southwestern United States. The type is Mr. Goodding's no. 666, secured at "The Pockets," on the Virgin River, in southern Nevada, April 30, 1902.

Helianthella Covillei, n. n.—*H. argophylla* Coville, Contrib. U. S. Nat. Herb. **4**: 132; *Encelia grandiflora* Jones, Proc. Cal. Acad. Sci. II. **5**: 702.

While working out the preceding species I naturally looked up all of the species of Encelia. As a result of this study I gained, with much difficulty, a conception of some of the species as understood by M. E. Jones. I feel satisfied that he is right in asserting the distinctness of the plant described by Dr. Coville (*l. c.*) from the *Tithonia argophylla* of Eaton, Bot. King. Exp. 423. On the other hand, he does not seem to be right in taking Coville's plant out of Helianthella, and in either genus Jones' specific name is untenable. I refer it back to Helianthella, therefore, naming it for Dr. Coville, who has furnished us with a clear and full diagnosis of it.

Bebbia aspera (Greene), n. sp.—Stems slender, the woody basal portion with gray fibrous bark, the herbaceous stems subcinerous with scattering abruptly upturned white scabrous often deciduous hairs from a papillate base: leaves nearly linear; the lower opposite, 2–4 cm long; the upper alternate, small and finally reduced to subulate bracts; pubescence similar to that of the stems: heads in an open corymbose panicle, 10–15 mm high, canescently pubescent: corollas yellow: style-tips slender-subulate, exserted, recurved: receptacle flat, chaffy throughout: the bracts linear-lanceolate, scarious, with base inflexed and partly enclosing the akene: akene broadly linear-clavate, with an evident epigynous disk: pappus of 20–30 plumose bristles as long as the corolla.

Never has a plant come into my hands that was so difficult to place. Superficially it has one or two eupatoriaceous characters, but the real characters unite it to the Helianthoideae. Inadvertently overlooking Greene's genus Bebbia, I applied to Dr. B. L. Robinson for assistance, writing him as follows: "This plant may get into the Helianthoideae. Here by a little amplification of characters it might be included in the Verbesineae or in the Madiae. If in the former, near Varilla; if in the latter, near Layia." I mention this to show that to one to whom the plant was wholly unknown it appeared in such a way as to confirm exactly the views expressed by Greene in the diagnosis of the genus (Bull. Calif. Acad. 1:179).

In regard to the elevation of *Bebbia juncea aspera* Greene (*l. c.*) to specific rank, I believe that no one who will take the trouble to compare the description of the *B. juncea* from Cedros Island, which furnished the type, with the full description of the inland forms will question their distinctness.

The foregoing description was drawn from plants collected by Mr. Goodding at Rioville, Nevada, May 6, 1902, no. 720. It is a low shrub 3–7 dm high, occurring on dry sandy hillsides.

Hymenopappus eriopoda, n. sp.—Perennial; the caudex decidedly woody, multicipitous, forming a large dense tuft; stems single from each crown, simple, 0.5–1 m high, leafy for more than one-half the height, more or less lanate-pubescent, glabrate upward: leaves numerous, glabrate, some lanate pubescence on the petiole and rachis, bipinnately divided into filiform lobes rarely more than 0.5 mm broad; petiole and rachis flattened-semiterete; the primary divisions 2–5 cm long; the secondary 1–2 cm; root-leaves numerous, crowded on the crowns, their bases involved with the stem in a dense white pannose tomentum, including the petiole 15–20 cm long; stem leaves 5–7, the uppermost merely pinnate: peduncles axillary, from the two or three uppermost leaves and from as many minute bracts, very slender, monocephalous, or developing 1 or 2 accessory heads on filiform pedicels, 1–3 dm long, the lowest usually much elongated: heads about 12 mm high: involucre rusty-tomentose, shorter than the disk; its scales in 2 series, mostly oblong, or oblong-elliptic, obtuse, with scarious margin and tips, rarely purplish: corolla tube obscurely glandular-pubescent, very slender, about 3 mm long, expanding into an equally long broadly tubular throat, which is three times as long as its lobes; akene 5 mm long, somewhat enlarged upward, pubescent especially on the angles; pap-

pus of numerous linear-oblong obtuse scales half as long as the corolla-tube.

The two related species are *H. lugens* Greene and *H. macroglottis* Rydb., the species now described making the third in the series of long-throated forms (see Rydberg, Bull. Torr. Club **27**:636).

Type no. 880, by Mr. Goodding, who reports it as abundant in "rocky volcanic draws" near Diamond Valley, Utah; May 19, 1902.

Tetraneuris epunctata, n. sp.—Caudex simple or with 2-several crowns: leaves crowded on the crowns, glabrate and bright green, with a few long whitish scattered hairs, wholly free from the punctate glands so usual in the genus, some microscopic resin particles present, narrowly spatulate or oblanceolate, 2–4^{cm} long, the margined petiolar bases imbricated on the crowns but not involved in the usual wool of the other species: scapes simple, ebracteate, 1^{dm} or less high, sparsely silky-canescent and obscurely granulate: heads large, 25–30^{mm} broad when fully expanded: involucre silky-lanate; the green tips of its oblong acute bracts mostly free from the wool: the bright-yellow rays about 12^{mm} long: disk corollas penicillate glandular-pubescent on the lobes: pappus scales nearly as long as the disk corollas, obovate, abruptly long-acuminate.

The type of this excellent species is no. 1236, collected by Mr. L. N. Goodding near the Dyer Mine in the Uintah Mountains, Utah, July 3, 1902. Most of the species in this genus are xerophilous plants and strictly vernal, occurring on broken ridges of the plains or on denudated foothills. In the species before us we have an inhabitant of moist subalpine slopes, occupying a belt from 9,000–12,000 feet in altitude. No. 1374 by the same collector was obtained above timber line.

Tetraneuris eradiata, n. sp.—Densely silky throughout: caudex short, of one or more crowns, slightly lanate and covered with the expanded bases of the petioles: leaves crowded on the crowns, linear or narrowly oblanceolate, 5–8^{cm} long, the short petiole margined and expanding at its scarious base: scapes slender, 12–25^{cm} high: heads wholly eradiate, 1^{cm} or more high, the disk almost orange or tinged with brown: pappus-scales obovate, glistening-white, tipped with a slender awn, including the awn almost as long as the silvery akene and scarcely shorter than the corolla.

Collected on steep mountain side at the head of the Middle Fork of Powder River, Big Horn Mountains, by Leslie N. Goodding, July 18, 1901, no. 276.

Gaillardia gracilis, n. sp.—Perennial from a woody root: stems usually several, simple or sparingly branched, slender and somewhat virgate, 5–7^{dm} high, the upper half naked-pedunculate, straw-colored, striate and nearly glabrous: leaves softly and sparsely short-pubescent, oblanceolate in outline, 4–8^{cm} long including the margined petiole, from entire to deeply pinnatifid with linear or broader lobes: the bracts of the involucre moderately canescent, narrowly lanceolate-acuminate, green and the tips somewht reflexed: rays yellow, cuneate, deeply cleft (nearly divided) into broadly linear obtuse lobes: disk purplish-brown: the corolla-teeth short-triangular, without tip of any kind, the penicillate pubescence short: akenes short-turbinate, densely long-villous, about equaling the numerous aristiform fimbrillae of the receptacle: pappus of 10 narrowly lanceolate paleae, as long as the rather broadly tubular corolla.

This will have to be looked upon as segregated from *G. pinnatifida* Torr. I take as typical of *G. pinnatifida* the plant of southern Colorado, southward and eastward. This is known by its almost scapose stems (the leaves being crowded on the crowns or at least well towards the base), by its canescent pubescence, and the fine purple of the disk which extends at least to the veins and the lower half of the ray. *G. gracilis* is twice as tall, with indurated base, leafy to the middle or above, rays wholly yellow and cleft almost to the disk.

The type is no. 894. Mr. Leslie N. Goodding, Diamond Valley, Utah, in deep hot cañons.

Arnica arcana, n. sp.—Tufted or cespitose in rock crevices, about 3^{dm} high: stems slender, minutely granular-glandular especially upward: leaves dark-green, denticulate, somewhat granular-glutinous; root-leaves oblong-oblanceolate, 2–4^{cm} long, on very slender petioles longer than the blade; lower stem leaves small, broadly oblong, sub-acute at apex, abruptly narrowed at base to short margined connate-sheathing petioles; middle stem leaves lanceolate, sessile or nearly so, 3–5^{cm} long; the foliar bracts similar but smaller: heads usually three, on subequal peduncles 5–10^{cm} long; more rarely 1 or 2 smaller additional heads on short slender peduncles proliferous from the base of the central

head: involucre turbinate-campanulate, about 1 cm high, shorter than the disk; its bracts in two series, the outer broadly linear, short-acuminate, minutely glandular, the inner narrower, subscarious: rays orange-yellow, obscurely 3-toothed: disk corollas with narrow minutely pubescent tube as long as the gradually dilated throat: akenes linear, dark, sparsely hispidulous.

After deliberating on this for a long time and failing to decide upon even its nearest ally, I submitted it to Dr. Greene, who replied as follows: "This I can refer to no known species; yet it is a feeble thing as to any character." Nevertheless, it seems well to place it on record and to distribute to the herbaria specimens which will enable our students to judge for themselves whether it is a species with "feeble" characters or not.

The type is no. 377, from Doyle Creek, Big Horn Mountains, Wyo., July 26, 1902; collected by Mr. Goodding.

Tetradymia axillaris, n. sp.—A shrub mostly less than 1 m high: stems several from the base, these freely and somewhat fastigiately branched at summit, all very white with a close fine permanent pannose tomentum: spines widely divaricate but not reflexed, very straight, slender, rigid and pungently acute, 2–4 cm long, tomentum somewhat floccose and rather early deciduous: leaves fascicled in axils of the spines, green and glabrous, somewhat fleshy, linear subulate, very unequal, 5–12 mm long: heads solitary, axillary, 5-flowered, on glabrous peduncles as long as the oblong-cylindrical head: bracts of the involucre 5, about 1 cm long, somewhat carinate and rigid, glabrous: pappus bristles much surpassing the copious hairs of the akene.

This relative of *T. spinosa* Hook. & Arn. I was at first inclined to refer to Jones's var. *longispina* of that species. With that variety it has some points in common, but because of the relatively long internodes of the stems, the straight rigid spines which are 3–5 times as long as the fascicled leaves, the glabrous heads, and peduncles which are solitary in the axils, it seems as impossible to unite it with that variety as with the species.

The type no. 917 is from Meadow Valley, Wash., southern Nevada, collected by Mr. Goodding, May 22, 1902.

MISCELLANEOUS SPECIES.

Cuscuta Anthemi, n. sp.—Stems delicately slender-filamentous, only 2 or 3 dm long: flowers sessile in capitate few-flowered clusters about 5 mm in diameter: calyx-lobes broadly ovate, acute,

united below the middle, somewhat imbricate, equaling or at first surpassing the corolla: corolla less than 2 mm long; its lobes ovate, acute, equaling or longer than the broadly campanulate tube: scales oval, fringed around the summit with short processes: filaments about as long as the anthers: capsule globose, about 1 mm in diameter: stigmas linear, purple, as long as the distinct equal styles; stigma and style together 1 mm long: ovules 4, usually but 1 maturing.—On *Artemisia gnaphalodes*. Wyoming.

When Dr. Rydberg published his *Cuscuta gracilis* (Bull. Torr. Bot. Club 28: 501), founding it in part upon material that had passed for *C. epilinum*, I was at first inclined to doubt the presence of indigenous species in this country possessing the characters that Gray and Engelmann had considered as possessed only by old world species. I am satisfied now, however, that both types occur here. Species undoubtedly indigenous and having characters clearly separating them from the European forms, with which we have been wont to ally them, leave no room for doubt.

The species now proposed was collected in the Seminole Mountains, Wyo., by Mr. Elias Nelson in 1898, no. 4936. It was found on *Artemisia gnaphalodes*, but I have no doubt it will be secured on other species of the Anthemideae.

Pectocarya miser, n. sp.—Minutely appressed-strigose, branched from the base, the several stems filiform, spreading, 5–20 cm long: leaves linear, imperfectly opposite, mostly less than 1 cm long, the floral one of the pair reduced or wanting: flowers singly at the nodes: nutlets geminate, very flat, irregularly and narrowly winged on the sides, sides and apex bordered with hooked bristles, the dorsal disk slightly keeled and glandular-hairy.

Known only from the type locality, Point of Rocks, Wyo., where it was collected by the writer, June 15, 1898, and distributed under no. 4741 as *P. penicillata* H. & A.

Orobanche xanthochroa Nels. & Ckll.,[1] n. sp.—Glabrous, 20–25 cm high: stem bracteate: the bracts large (20 mm long and 7 mm broad at the base), the upper of these covering rudimentary flowers: spike 10–12 cm long, about 38 mm broad, densely flowered: floral bracts single, acuminate-lanceolate, 17 mm long: flowers entirely pale yellow: upper lip large (9 mm broad, surpassing the calyx by 7 mm), rounded, entire or with two slight notches:

[1] The characters of this plant were worked out by Professor Cockerell from the living plant. It has had further study in the herbarium.—A. N.

anthers with a fringe of long hairs on each side, but not otherwise hairy; anther cells caudate basally: calyx with five short triangular lobes about 2^{mm} long: discoid stigma about 3^{mm} broad: capsule oval, somewhat pointed apically, 10–11^{mm} long, about 7^{mm} in diameter; style persistent, nearly 9^{mm} long, strongly curved: seeds very numerous, irregularly angular, light-brown, obscurely pitted.

The affinity of this species is with *Orobanche Ludoviciana* Nutt. It turns ferruginous on fading or after bruising. First collected, June 7, 1903, by Dr. M. Grabham, at Pecos, N. M., where it occurs as a parasite on the roots of Quercus.

The Rocky Mountain Herbarium,
Laramie, Wyoming.

THE EVOLUTION OF THE SEX ORGANS OF PLANTS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LV.

FLORENCE LYON.

(WITH SIXTEEN FIGURES)

WITHIN the last twenty-five years there have been repeated attempts to bridge the chasm between the bryophytes and algae, but no transitional stages have been found between the unicellular sex organs of the green algae and the multicellular archegonium and antheridium of the bryophytes.

Morphologists have persistently fixed their attention upon the Chlorophyceae in their search for ancestral conditions, and have regarded the brown and red sea-forms as aberrant. Perhaps this is because no bryophytes, so far as is known, occur in salt or brackish water, and but few forms of brown algae exist in fresh. More likely, the attention focused on the alternation of generations, and the suggestion of an antithetic sporophyte and gametophyte in Coleochaete, Oedogonium, and Ulothrix, have been so dominant that the other groups have been set aside as unfruitful fields for investigation. All morphologists of note have laid stress upon the development of the sex cells and the sex organs as of the greatest importance in determining any theory of evolution. While the vegetative part of the gametophytes of bryophytes and pteridophytes is most changeable, appearing in many bizarre forms in the leafy jungermannias and the mosses, and varying from thin sheets of cells of the most primitive sort to tuberous bodies with highly differentiated tissues in the club mosses, simulating those of the higher plants, the sex organs of a group retain, as a rule, a constant monotonous type, varying from one another in related genera only in unimportant details, such as the length of the neck, the presence or absence of a stalk, the total emergence, or the whole or partial submergence of the archegonium in the vegetative tissues.

In the course of conducting university classes in general morphology for the past few years, I have had occasion to examine many preparations of representative plants of the chief groups, and have become impressed by the comparative frequency of certain irregularities in the development of the sex organs, particularly in pteridophytes, that show their plasticity and are suggestive from the evolutionary standpoint. I am inclined to look upon the "monstrosities," as biologists are fond of calling organisms which do not conform to a morphological rule of thumb, as presenting hints of ancestral conditions which afford at least a logical theory of the origin of the sex organs.

In a recent paper on the "Origin of the archegonium," Davis (1) has given a series of diagrams of hypothetical transitional forms to illustrate his view of the evolution of the sex organs from a plurilocular sporangium similar to that of *Ectocarpus virescens*. His theory would be far more convincing had he cited actual rather than hypothetical transitional forms, and such evidence is not difficult to obtain.

In an article on the development of the archegonium of mosses, Hy (2) describes an organ of mixed sexual character which has the egg apparatus at its base, and is distinctly spermatogenous at the summit. This phenomenon, he says, is not uncommon, occurring in several species — notably in *Atrichum undulatum*. Unfortunately he gives no figures of this interesting variation. Many instances of a similar nature in *Mnium cuspidatum* were observed by students in the Hull Botanical Laboratory two years ago, and figures of bisexual organs from this material appeared in Holferty's (3) paper in the February number of the BOTANICAL GAZETTE. None of the plants in that collection was mature enough to determine the future of the gametes, or whether the sperms were actually formed.[1] That the tissue appearing in a single organ consisted of immature cells of two kinds there can be no doubt. That antheridium and archegonium are homologous organs is a logical conclusion from the fact that cells at the apex of a moss shoot may indifferently develop into male,

[1] Since the above was written, specimens have been secured with perfectly typical moss sperms which were discharged from the antheridial region above the egg.

female, or bisexual organs. Further evidence to support this view of the homology of the sex organs, and that the simple axial row of an archegonium is reduced from forms which had two or more, is furnished by several groups of pteridophytes.

In three species of Equisetum (*E. hiemale*, *E. arvense*, *E. limosum*), the archegonium frequently consists of an egg, a shallow ventral canal and two neck canal cells pyriform in shape and lying side by side (*fig. 1*). Jeffrey (**4**) regards an archegonium of this form as typical. In his monograph he figures *E. arvense* and *E. hiemale* with two neck canal cells in this position, and the text calls attention to this characteristic.

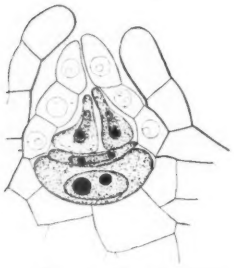

FIG. 1.— Longitudinal median section of archegonium of *Equisetum limosum*, showing the lateral position of the neck canal cells.

I have a few specimens showing the same conditions in *Isoetes lacustris* (*fig. 2*). Campbell (**5**) found two laterally placed nuclei in the single neck canal cell of *Isoetes echinospora* with no intervening wall.

Occasionally a division of the lowermost cell of the axial row, probably the "central" cell, occurs in *Selaginella apus*. This possibly may be interpreted as an egg and a ventral canal cell laterally placed (*fig. 3*). That they may both function as eggs seems evident from the case of polyembryony shown in *fig. 4*.

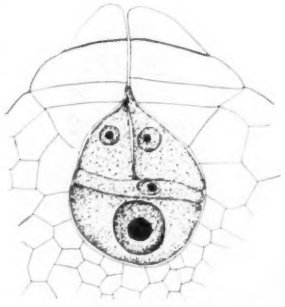

FIG. 2.—Longitudinal median section of an archegonium of *Isoetes lacustris*, showing lateral position of the neck canal cells.

But much more striking are the sex organs of at least two species of Lycopodium. It will be remembered that the gametophytes of only eleven species of this genus have ever been discovered, and that these differ so markedly among themselves as to be divided by Pritzel into five categories. They range from the simplest to the most complex gametophytes known, with the

possible exception of certain mosses. I have a prothallus of *Lycopodium complanatum* bearing fifty or more archegonia; of these more than half have binucleate canal cells, and there are two instances in which the egg cell is included in the doubling (*fig. 5*). The remarkable number of cells in the axial row (often 14–16) marks these as unique amongst known archegonia of the imbedded type. I do not recall that Bruchmann (**6**), to whose notable work we are indebted for the knowledge of the gametophytes of this and other European species of Lycopodium, mentions the multiplication of the fertile cells, although one of his figures certainly shows it; but Treub (**7**) lays stress on the fact that the canal cells of *Lycopodium Phlegmaria* show a marked tendency to form two axial rows. I have taken the liberty of copying two of his figures (*figs. 6, 7*). Treub says that he frequently found archegonia of this sort, and all of his figures show it. He observed an interesting "monstrosity" twice. This was an archegonium whose upper neck canal cells increased to an abnormal number and were spermatogenous in character. He neglected to illustrate this duplex organ, but in this connection he recalls the similar phenomenon referred to by Hy (**2**) in mosses, and regards it as of importance. In all these variations there has been a tendency to increase the number of fertile cells by a lateral multiplication of the axial row.

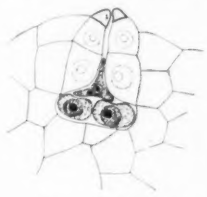

FIG. 3.—Longitudinal median section of an archegonium of *Selaginella apus*, showing lateral position of egg and ventral canal cells.

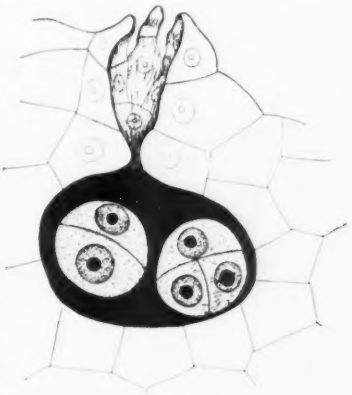

FIG. 4.— Longitudinal median section of archegonium of *Selaginella apus*, showing embryo derived from egg and ventral canal cells.

In quite another category is the archegonium of *Adiantum*

cuneatum (*fig. 8*). Here two eggs are separated by two ventral canal cells lying below the two typical neck canal cells. Coker (8) has described and figured an archegonium of *Mnium* sp. with two eggs lying one above the other and each with a ventral canal cell. A *Funaria hygrometrica* preparation in my possession also shows this variation.

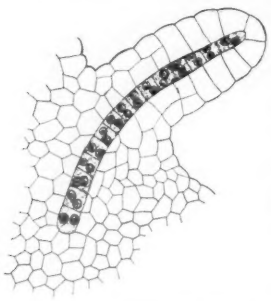

FIG. 5.—Longitudinal median section of an archegonium of *Lycopodium complanatum*, showing the lateral multiplication of the cells of the axial row.

The sex organs of some fern prothalli[1] gathered in an Indiana bog last summer display remarkable plasticity of form and character. The sex organs were developed in profusion on these prothalli, and the mat as it was stripped off a log appeared beset with young sporophytes. Everything in their appearance bespoke most luxuriant growth. Upon sectioning this material, the number of embryos formed from the sexual spores was found to be limited. Many of them are apogamous, developing most frequently from the "jacket" cells of the thallus in immediate contact with the egg. The archegonia were perfectly normal in development, the neck canal cells dissolved, the neck opened and became choked with vigorous-looking sperms, but for some reason in most cases the egg failed to become the progenitor of the sporophyte. I have not been able to determine whether there is fusion of sperms with the cells that give rise to the apogamous embryo, although there is some evidence of that condition. The archegonium neck behaves peculiarly. Instead of breaking down or becoming brown, as is the ordinary rule, in certain cases the lowermost neck cells branch and develop rhizoid-like filaments or even antheridia which mature

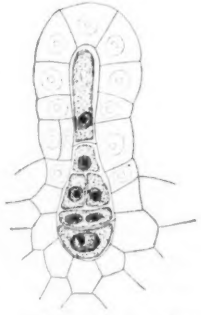

FIG. 6.—Longitudinal median section of an archegonium of *Lycopodium Phlegmaria*, showing the "doubling" of the axial row.—After TREUB.

[1] The species was undetermined. In the immediate vicinity were growing three species of Osmunda. Probably the gametophytes belong to this genus.

and whose sperms have every appearance of being normal. The number of sperms produced, however, may be smaller than usual. Sometimes two or three antheridia are developed from the neck cells of the same archegonium (*fig. 9*). This is cogent evidence that the cervical cells of an archegonium are sterilized gametogenous cells which may regain potentiality. Goebel (9) describes the same phenomenon of antheridia developing from the neck cells of archegonia of *Hemionitis palmata* and *Lygodium japonica*. He comments thus: "Wir können dieses Verhalten als eine Altenserscheinung betrachten." But that can hardly be the explanation of the phenomenon in this case, for the prothalli were young and displayed unusual vigor. All stages of archegonia and antheridia appear in a single thallus.

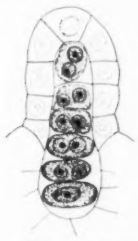

FIG. 7.—Longitudinal median section of an archegonium of *Lycopodium Phlegmaria*, showing two rows of neck canal cells.—After TREUB.

Aberrant antheridia have been less frequently noticed. The form of the male organ seems to be singularly simple and monotonous throughout the bryophytes. I have found a variation of frequent occurrence, however, in the antheridium of *Atrichum angustatum*. The spermatogenous cells are separated into two groups by a transverse septum consisting of a single layer of cells formed from fertile cells that ceased to divide early in the development of the organs, and at about the period at which the wall is differentiated. Sometimes these two groups matured *pari passu;* again, the sperms were ready to escape from the upper or under chamber indifferently, while the other group was immature (*fig. 13*). This division of the sperm mass is the rule in *Selaginella apus* either with or without the intervening diaphragm as in Atrichum and in certain Hydropterideae. As is well known, at

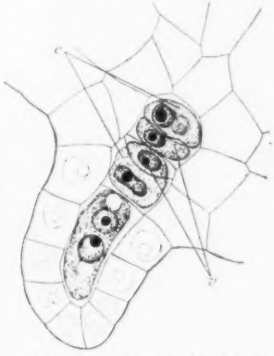

FIG. 8.—Longitudinal median section of an archegonium of *Adiantum cuneatum*, showing double egg apparatus: *e*, eggs; *v*, ventral canal cells.

the moment of the development of an antheridium, when the wall is delimited from the potential spermatogenous cells, the latter are few in number and their walls become so much thicker than those which appear in their subsequent divisions, that the mature organ in section displays conspicuous plots, which frequently mature at different periods. Not rarely one or more of these cells fails to produce the same number of generations as the others, and so certain large spherical cells (for they separate from one another) may sometimes be found intermingled with mature sperms (*fig. 10*). I am inclined to regard these as eggs. Campbell reports budding of "secondary" antheridia from the stalk of an older Anthoceros antheridium, and the same thing has been seen in this laboratory. This variation is analogous to the formation of antheridia from the neck cells of the fern archegonia.

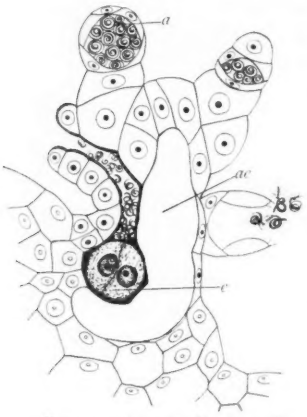

FIG. 9.— Longitudinal median section of "monstrous" fern archegonium, showing three antheridia developed from neck cells (*a*), an apogamous embryo (*ae*), and a normal two-celled embryo in the venter (*e*).

The antheridia of the apogamous fern prothalli described above were also *sui generis*. Those developed in young prothalli were typical. But those formed among the archegonia were frequently double, two antheridia on a single stalk (*fig. 11*). Upon investigation, this proved to be a case of budding of a secondary antheridium from another well advanced. Both antheridia produced perfect sperms that were voided. A frequent variant on this was a rhizoid-like branch from the stalk of the antheridium. A most interesting case of apogamy was observed twice. In these cases the embryo was formed from the stalk cell of an *antheridium!* This has not been observed, I think, by Lang (10) or any other investigator who has worked on apogamy.

In this connection and *à propos* of this unstable and plastic con-

dition of the sex cells the preliminary announcement of apogamy in *Selaginella rupestris* may be made. It may be recalled that this is the form of Selaginella with a reduced number of functional megaspores (one or two) which are not shed until the embryo is fully equipped with leaves and root. In certain localities, the microspores are rarely produced and the embryos are frequently formed from the initial cell of the archegonium. Until the third or fourth division of this initial, it is impossible to determine whether a normal archegonium will result or an embryo.

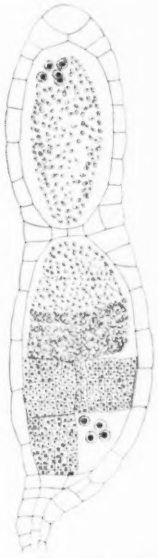

FIG. 10.— Antheridium of Atrichum, showing two chambers.

The development of the antheridium of the Anthoceros group has until recently been looked upon as unique. The male organ of no other group is known to arise from a hypodermal cell. The fact that this antheridium, sunken below compact tissue, has a well-developed wall, militates against the view that it is a primitive form. Emma Lampa (11) has noted Anthoceros plants which develop emergent antheridia arising from superficial cells, similar to those of other groups of liverworts, and believes them to be a reversion to an ancestral form. I do not regard them in the same class with the sunken sex organs of Lycopodium, Botrychium, Phylloglossum, Equisetum, and the archegonia of Selaginella, Isoetes, and Anthoceros, which have no sterile jacket. These, to my mind, represent a different line of evolution from the emergent sex organs with long necks and stalks. Davis's theory of the pluriculocular sporangium-like body of a definite form and bisexual character, essentially an emergence of fertile tissue from the surface of a hypothetical thallus body which came to

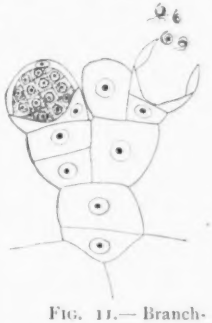

FIG. 11.— Branching antheridia of Osmunda (?).

adopt the land habit, seems to account plausibly enough for the *emergent* archegonium and antheridium of the Marchantia and moss type, but it is less convincing as the ancestral form of sunken sex organs, particularly those which have "lost" (?) stalk, wall, and other sterile cells except the cover. The sunken sex organs of all plants develop from an epidermal cell of the *dorsal* surface of the gametophyte, except in ferns and the Anthoceros forms, in which they are frequently produced on both dorsal and ventral sides. This is true of Anthoceros, but I know of no authority that it is the case in Notothylas or Dendroceros.

In speculating upon the early development of the sex organs and the significance of the variations noted above, one fact stands out prominently, that the cells concerned in the formation of the sex organs are more plastic and indifferent than has been believed, and that the region giving rise to the sex organs not infrequently displays a latent gametogenous character. One might go back further to a stage preceding the emergent plurilocular sporangium and postulate as a point of departure thallose algae with indeterminate masses of reproductive cells which pass through the plant from one surface to the opposite. With increasing thickness of the thallus, sterilization will be most likely to appear at the center of the mass and, working progressively from the center outward in both directions, would result in layers of gametogenous or sporogenous cells at each surface. These concrete masses by further sterilization might become discrete patches or "organs," if one chose so to designate them. Cover cells would arise from sterilization of the superficial cells of these regions. Up to this point there might be isogamy, or even the indefinite condition that obtains in Ulothrix, where zoospores cannot be distinguished from gametes. Differentiation of sex cells could be accounted for by certain cells ceasing to divide earlier in their development than others, resulting in eggs, as contrasted with those that by repeated divisions work out sperms. In this way some of the primitive organs in all probability would be bisexual. The emergent sex organs could evolve from these sunken forms by pushing the steriliza-

tion idea further and considering eruptions to arise from the thallus. This fertile branch could easily evolve into an archegonium or an antheridium, or an organ of mixed character.

But however fascinating and probable a scheme of evolution is, it deserves scant attention unless it can muster at least circumstantial evidence to support it. Illustrations of all the phases which I have suggested may be readily found among the algae, especially the browns. *Ulva lactuca* is a thallose green alga which consists of two layers of cells throughout, except at the period of reproduction, when irregular masses of these cells subdivide into gametes with two cilia, or zoospores with four. Thus in certain regions the thallus becomes eight or even sixteen layers of cells thick, all of these being fertile (*fig. 12*). *Phyllitis caespitosa* consists of sterile cells in the central region of its thallose body, while the layer of cells on each surface subdivides into gametogenous or sporogenous cells (*fig. 13*). *Punctaria latifolia* has patches of these cells separated into primitive organs by sterile tissue (*fig. 14*). Moreover, these patches are distinctly of two sorts, the one consisting of few large cells, the other of small cells which discharge sperms said to fuse with the larger cells (eggs?). Zanardinia has exogenous sex organs of two kinds (*fig. 15*). The branching of the male sex organs is of interest and may suggest a clue to that aberration in Anthoceros, Mnium, and the ferns hitherto

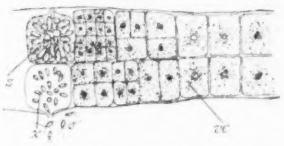

FIG. 12.—*Ulva lactuca:* dorsiventral section of thallus, showing vegetative cell (*vc*), cells in process of forming zoospores and mature zoospores of two sizes (*x*, *z*). Diagrammatic.

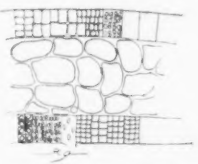

FIG. 13.—*Phyllitis caespitosa:* dorsiventral section of thallus, showing reproductive cells at both surfaces; sporangia form a continuous layer on each.—After RIOCREUX.

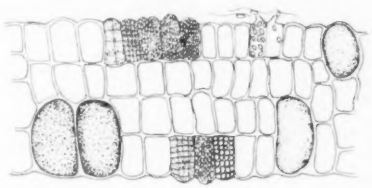

FIG. 14.—*Punctaria latifolia:* dorsiventral section, showing sexual cells in patches on both surfaces.

described. In his anatomical study of Porphyra, Janczewski (12) describes the two sorts of sexual cells produced, the "antherozoids" and the "octospores," and says that he considers the latter as antheridia whose final segmentation has been arrested. He says further: "Je considère comme une *anthéridie* le groupe d'*anthérozoïdes* siégeant dans une maille du réseau, correspondant à une octospore, et issu par conséquent d'une cellule végétative. Le développement des anthéridies est d'abord tout à fait semblable à celui des octospores. Il obéit ensuite aux mêmes règles, et l'on dirait que les octospores ne sont que des anthéridies dont la segmentation ultérieure a été arrêtée."

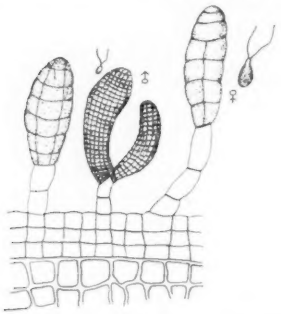

FIG. 15.—Portion of dorsal surface of Zanardinia, showing the emergent sex organs.

This view suggested to me that the conditions sometimes found in a bryophyte antheridium might be analogous or even homologous. Are the cells which are arrested in division and assume a spherical shape (*fig. 10*) homologous with eggs, and is their appearance a return to ancestral condition?

The theory I have outlined would account for sex organs on or near both dorsal and ventral surfaces, as they are known to occur in Anthoceros, in certain thallose jungermannias, and in ferns. It would explain the sunken sex organs consisting of fertile cells not surrounded by a wall, formed of sterile sister cells, as the archegonium of Anthoceros and the antheridia of Equisetum and Lycopodium. According to such a theory, existent transitional stages might be expected in which the sex organs would not have assumed a definite shape nor a definite number of cells. Precisely this indeterminate condition is to be found in certain

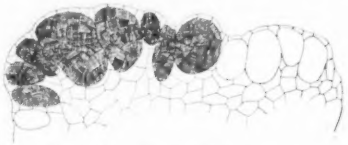

FIG. 16.—*Lycopodium annotinum:* dorsiventral section of portion of gametophyte, showing antheridia of indeterminate size and shape.

species of Lycopodium, notably *Lycopodium annotinum* (*fig. 16*), in which the antheridial region is made up of patches of spermatogenous cells quite indefinite in contour and varying in number. There is no wall of sterile cells. This appearance is not due to difference in state of development, or because antheridia are cut in different planes, as might be inferred from a single section. I have seen antheridia at maturity varying in the number of sperm cells from fifty to more than three hundred. Not infrequently groups of spermatogenous cells derived from separate initial cells abut upon one another with no intervening cell tissue, but it is generally easy to trace the individual groups. Sex organs of this type are logically explicable by the progressive sterilization of an indefinite superficial region, but it requires a *tour de force* to imagine the modification of an emergent sporangium of definite form into the sunken condition displayed by Lycopodium.

Archegonia and antheridia of few cells are generally regarded as the most advanced. From this standpoint, the sex organs of this species of Lycopodium are the most primitive ones known. This of course does not take into consideration the anomalous bisexual organs of *Mnium cuspidatum* described by Holferty. On the other hand, no gametophyte, with the exception of certain mosses, is so complex in the variety and specialization of its vegetative tissues as that of *Lycopodium complanatum* or of *Lycopodium annotinum*. To be sure, the gametophyte of *Lycopodium cernuum* by contrast is exceedingly simple, and that of Phylloglossum is said by Thomas (**13**) to show little internal differentiation of cells; but cases are frequent among animals where somatic tissues become elaborate and highly organized, while the sex organs lag behind and retain great simplicity. This would be expected in organisms where the struggle for existence is great, as it may have been among the Lycopodiums, if one may judge from the capricious germination of the spores. Moreover, the symbiotic relation of the club mosses with a fungus indicates difficulties in development. Attempts have been made repeatedly to germinate the spores of the club mosses, but the results obtained thus far have been unsatisfactory. The life history of every gametophyte of Lycopodium now discovered is full of gaps.

Several years ago, in his brilliant monograph on the evolution of the sporangium, Bower (**14**) suggested that emergences erupted from an indefinite concrete imbedded mass of sporogenous cells, and by progressive sterilization and branching resulted in discrete sporangia. In support of his view, he marshaled existent bryophyte and pteridophyte forms that he regards as analogous to those that may have appeared in the direct line of evolution. The same kind of argument may be applied to the origin of the sex organs. I have no idea that any of the brown or red algae represent lineal ancestors of the liverworts or ferns as we now know them; but if the Phaeophyceae are perchance an offshoot from green algae, the method in which they produce their reproductive cells may be like that of their forbears, from whom also the archegoniates have probably evolved. It is possible that the investigations of apogamy now proceeding will throw some new light on the subject. I hazard the suggestion that the origin of the apogamous sporophyte is among latent gametogenous cells of the thallus, which under unknown conditions develop sporangia without the formation of sex organs. Such a hypothesis may seem rash, but there is, I think, no inherent improbability in the theory, while it furnishes a suggestive line for investigation among the brown algae, which is a sufficient reason for its being. If Farmer's (**15**) preliminary announcement of the fusion of the nuclei of neighboring cells of fern prothalli, as a step preliminary to the formation of the apogamous sporophyte, is confirmed, are these fusing cells to be regarded as stable vegetative cells, or as potential isogamous gametes? If the latter, is it not conceivable that they are surviving cells of a former fertile region which normally are sterile, but on occasion may regain potentiality?

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BRIEFER ARTICLES.

THE STRUCTURE OF THE FLOWERS AND THE MODE OF POLLINATION OF THE PRIMITIVE ANGIOSPERMS.

THE purpose of this paper is to show how some questions involved in the phylogeny of angiosperms might be regarded from the point of view of the anthoecologist. The proposition to be offered is that the primitive angiosperms were entomophilous, and that the anemophilous ones are metamorphosed entomophilous flowers whose seemingly simple structures are degraded, not primitive.

The characteristic anemophilous flower has a pistil with a one-celled ovary containing a single ovule and ripening into a one-seeded indehiscent fruit. The characteristic entomophilous flower has a pistil with several ovules which ripens into a several-seeded dehiscent fruit. The explanation of the monospermy of the Anemophilae and the polyspermy of the Entomophilae is obvious when one considers the difference in the conditions of pollination. Even with a large plumose stigma the Anemophilae have enough to do to secure enough pollen for a single ovule. The Entomophilae with a small stigma can readily secure enough pollen for many ovules. The relation of many-seeded fruits to entomophilous pollination is emphasized in the orchids, where the high degree of polyspermy is correlated with the disposal of the pollen in masses. There are conditions under which entomophilous flowers become monospermous, and anemophilous flowers derived from them may show monospermy as an inherited character. But polyspermy is an entomophilous character.

Syncarpy involves polyspermy and is also an entomophilous character, the union of oligospermous fruits producing polyspermy. It is hard to imagine conditions under which an anemophilous plant would be likely to become syncarpous. Accordingly, in the absence of other entomophilous characters, and in spite of the presence of anemophily, plants may still retain the entomophilous characters of polyspermy and syncarpy. Syncarpy is important in diagnosing advanced stages of anemophilous metamorphosis because indications of syncarpy may be the only remaining evidence of a previous polyspermous condition. I also regard highly specialized inflorescences as entomophilous. At any

rate, a highly specialized inflorescence is no place to look for simple structures.

According to their stages of development, three sets of anemophilous plants may be recognized: (1) those closely related to entomophilous ones and evidently of recent origin; (2) plants whose development from Entomophilae is not so evident, but which have dehiscent polyspermous fruits, one-seeded dehiscent fruits, or one-seeded indehiscent fruits developed from pistils containing more than one ovule; (3) in large groups containing no entomophilous representatives, having one-seeded indehiscent fruits ripening from one-celled, one-ovuled pistils.

The considerable number of plants of the first set shows that the independent development of anemophilous plants from entomophilous ones has frequently taken place. It shows that the change is easy. The most recent cases are of genera belonging to entomophilous groups, which are themselves entomophilous, but contain anemophilous species: Thalictrum, Fraxinus, Sanguisorba (Poterium), Acer; Salix, also, if Warming is right in regarding the Greenland species of Salix as anemophilous.[1] Less recent are Ambrosia in Helianthoideae, Ricinus in Euphorbiaceae, Rumex in Polygonaceae, Platanus in Rosales, Amarantaceae in Centrospermales, Plantaginaceae in Sympetalae, Juncaceae in Liliales. On the other hand, none of the anemophilous groups have produced forms which could reasonably be regarded as recently developed entomophilous ones.

In the recent cases the fruit does not differ essentially from that of the entomophilous forms from which they were derived.

The Plantaginaceae compose the only anemophilous family of Sympetalae and show every indication of being recent. The stigma is single, but is, no doubt, modified from a completely compound one. The number of seeds varies greatly, but some of the flowers are subject to spontaneous self-pollination and others may be more or less etomophilous.

Populus has two to four stigmas, a syncarpous fruit with two to four valves, two to four parietal placentae, and numerous coma-bearing seeds. From these characters I would suppose that Populus was not only of entomophilous origin, but recent. It has seemed to me remarkable that Müller should have regarded Populus as a primitive anemophilous form and Salix as a recent entomophilous form derived from the same stock. For the relatives of Salicaceae I would look among the entomophilous polyspermous forms having similar fruit and seeds. So,

[1] Om nogle grönlandske blomster. Sv. V. Ak. Öfv. 1886: 116, 131, 158.

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from my standpoint, and in the absence of some other consideration, I would readily accept the view that the Salicaceae should follow the Tamaricaceae, the reduction of the flowers being correlated with close crowding in a specialized inflorescence. In regard to the entomophilous origin of Populus, it may be mentioned again that Warming regards the several species of Salix occurring in Greenland as anemophilous.

The relation of Amarantaceae to an entomophilous group and its recent anemophilous character is implied by the position to which it has been assigned. Some of the family are entomophilous and polyspermous. The more familiar anemophilous species are monospermous, but still retain the useless habit of opening to discharge a single seed.

Betulaceae has a pistil with two stigmas and a two-celled ovary with one ovule in each cell. The fruit is one-seeded and indehiscent, but was evidently developed from a polyspermous one.

Fagaceae usually has three stigmas, three-celled ovaries, with two ovules in each cell, ripening into one-seeded fruits. Sometimes, however, in Castanea, the fruit contains two or three seeds, although it has lost the power of discharging them. Here we have evidence of a change from a polyspermous, entomophilous condition.

The Juglandaceae have a pistil with two stigmas and an incompletely two to four-celled, one-ovuled ovary. The fruit is apparently syncarpous and the anemophilous condition only a stage in advance of that of the Betulaceae.

The Ulmaceae appear to be syncarpous. Ulmus has a pistil with two stigmas, a one to two-celled ovary with one to two ovules, and the fruit monospermous. Morus has two stigmas and a two-celled ovary.

The Juncaceae are placed in the entomophilous group of Liliales. Some of the species are entomophilous, others autogamous or cleistogamous. The anemophilous ones are polyspermous, indicating a recent entomophilous origin. The fruit is evidently tricarpellary.

On the supposition that the Typhaceae are representatives of primitive anemophilous monocotyledons, it is hard to account for the fact that Sparganium sometimes has two stigmas and a two-celled, two-ovuled pistil ripening into a two-seeded indehiscent fruit. Typha has the fruit dehiscent, although one-seeded, and the pollen in fours. The occurrence of persistent tetrads is of itself enough to establish a presumption of an entomophilous origin. Such compound pollen grains occur in Anonaceae, Magnoliaceae, Empetraceae, Ericaceae, Vacciniaceae, Epacridaceae, Pyrolaceae, Onagraceae, Amaryllidaceae, and Juncaceae—all entomophilous except the last. In connection with

the case of Typha may be mentioned the statement of Bentham and Hooker that some Araceae have "pollen in farciminula conglomeratum (pollen vermiforme)." The Typhaceae seem to be anemophilous descendants of the entomophilous Araceae. The reduction of the flowers seems to have been connected with close crowding on the spadix, followed by further reductions after the anemophilous habit was established.

In the Glumales we find a great group of anemophilous plants with the pistil one-ovuled and the fruit one-seeded. From the fact that the flowers are crowded in highly specialized inflorescences I would conclude that their seemingly simple structures are the result of degradation. The pistil has two or three stigmas, from which I conclude that the fruit is syncarpous and developed from a polyspermous stock. Anemophily may account for a stigma becoming plumose, but I do not see how it will account for the presence of two or three stigmas.

While I think the claims of any anemophilous plants which I know to being representatives of primitive anemophilous forms can be refuted without resorting to any speculative considerations, there are some speculative difficulties which may be mentioned. On the supposition that the angiospermous prototype was anemophilous, I can hardly imagine any conditions under which it would be advantageous for the ovules to become inclosed in a carpel. A single ovule could hardly be pollinated any better, and more than one could hardly be pollinated so well. If, on the other hand, the pollen was carried by insects, we can understand how a number of ovules might become inclosed in a carpel and be more effectively pollinated than they were before. So I am inclined to regard the angiospermous prototype as having been polyspermous and entomophilous. Here it may be well to cite the fact that the recently discussed cases of plants which are doubtfully dictoyledonous, or which seem to point more or less significantly to a line from which the dicotyledons and monocotyledons may have had a common origin, are entomophilous.

There are some considerations relative to pollinating agencies which may have had something to do with anemophilous metamorphosis. A change to wind pollination might be favored by close competition of entomophilous flowers for the attentions of anthophilous insects or by disturbances reducing the number of insects of that kind.

Some conditions in the behavior of bees may also have favored the resort of many diclinous plants to anemophily. The primitive anthophilous insects probably visited flowers chiefly for nectar. Adaptations

to them were secured by placing the nectar so that the visitor in obtaining it would strike the anthers in one case and the stigma in the other. The advent of the bees, which feed their young principally on pollen, and whose most abundant and most efficient visits are for that purpose, has changed the conditions. The flowers best adapted to bees are those whose receptive stigmas are so near the dehiscing anthers that the bees cannot collect the pollen without coming in contact with the stigmas. Diclinous, dichogamous, and large flowers are often visited by bees which rarely touch the stigmas. The diclinous plants particularly seem to suffer from having their pollen carried away by female bees which pay little attention to the pistillate flowers. Under these conditions it is a question whether anemophily would be much more expensive or precarious for many diclinous entomophilous flowers.

In many cases the views here advanced are not supported by the Engler and Prantl classification, and involve a criticism of that system. But they are supported by the modification of the systems of Engler and Prantl, and Bentham and Hooker, proposed by Bessey in the BOTANICAL GAZETTE **24**: 145–178. 1897, and, as far as they go, tend to supplement his conclusions regarding the taxonomy of angiosperms That author says nothing about the mode of pollination, but the forms which he selects as primitive involve the conclusion that the original forms were entomophilous. Bessey places a number of controverted families in entomophilous groups: Salicaceae after Tamaricaceae in Caryophyllales; Urticaceae in Malvales; Fagaceae, Betulaceae, and Juglandaceae in Sapindales; Typhaceae with Aroideae in Nudiflorae. —CHARLES ROBERTSON, *Carlinville, Ill.*

ARCTERICA, THE RAREST GENUS OF HEATHERS.

(WITH TWO FIGURES)

IN the Harvard University Herbarium is a specimen of an ericaceous plant which has a singular and interesting history. The specimen is a mere fragment, 43^{mm} in length, yet its characters are so clear and remarkable that Dr. Asa Gray in 1885 described it as a new species, *Cassiope oxycoccoides*,[2] and the present writer, while segregating two species from Cassiope under the generic name Harrimanella in 1901,[3] found in this plant sufficient characters to warrant setting it aside as a third genus, Arcterica.

[2] GRAY, A., Proc. Am. Acad. **20**: 300. 26 Ja 1885; GRAY in STEJNEGER, Proc U. S. Nat. Mus. **7**: 534. 27 Ja 1885.

[3] COVILLE, F. V., Proc. Wash. Acad. Sci. **3**: 569–576. *figs. 62–66.* 1901.

The home of Arcterica is Bering Island, off the coast of Kamchatka, remote geographically from any center of civilization, and having only occasional communication with its political parent, Russia. The specimen was collected by Dr. Leonhard Stejneger, of the United States National Museum, in 1882, when as a zoologist he was investigating the fur seals of the Commander Islands, to which group Bering Island belongs. The single twig of Arcterica was picked up accidentally among some specimens of *Bryanthus Gmelini*. In subsequent visits to the island Dr. Stejneger attempted to find the plant again, but was unable to rediscover it.

It was upon Bering Island that George Wilhelm Steller, the botanist, passed the winter of 1741–42, while thirty men out of seventy-six died from scurvy and exposure, including Bering himself, the leader of the expedition. While the survivors were rebuilding their boat, Steller busied himself with collecting, and by the time the expedition sailed from the island, on August 14, 1742, he had secured a fair representation of the plants which had flowered up to that time, 211 species altogether.

With the notion that Steller must have collected Arcterica on Bering Island, and that his specimens had lain unnamed for more than a century and a half in the great botanical gazophylacium of Russia, the writer in September last visited the herbarium of the Imperial Academy of Sciences, in the city of Peter the Great, and waited in breathless expectancy at the foot of a stepladder, while the courteous curator upon its summit explored the upper pigeonholes for Steller's specimens. At last the answer came down, in the form of that conclusive and irrevocable Russian *nyet*, with which we are more familiar in its Americanized form, "nit," recently current among street boys.

There seems to be little hope that other specimens of Arcterica will come to light, except such as may be discovered hereafter by some diligent collector who searches carefully for it on Bering Island. The exact spot on which it was found by Stejneger, on August 22, 1882, was "a rounded hill, about 300 feet high, just behind the fishing settlement of Saranna. The hill rises up from the shore of Lake Saranna, and is the first one when following the track of the dog sledges to the main village." The accompanying illustration and description will aid in the identification of the plant.

DESCRIPTION OF THE TYPE SPECIMEN OF ARCTERICA OXYCOCCOIDES.

Specimen a branched twig 43^{mm} in length, bearing leaves and flowers. (*Fig. 1.*)

Twigs 1^{mm} or less in diameter, minutely pubescent, bearing at intervals of 2–8^{mm} whorls of three leaves.

Leaves on petioles about 1^{mm} in length, oblong, 4–6^{mm} long, 2–3^{mm} wide, apparently evergreen, very thick, coriaceous, entire, smooth or with traces of pubescence along the margins or in the median groove on the upper surface of the leaf, the margins revolute, the stout midrib very prominent beneath, the blunt apex of the leaf bearing a large gland. The leaves bear a striking resemblance in size, form, and texture to broad leaves of *Chamaecistus procumbens*, but in the latter plant the lower surface is pubescent between the midrib and the margins, and the terminal gland is wanting. The terminal gland of our plant is similar to that of *Vaccinium Vitis-Idaea* and the South American species of Gaylussacia.

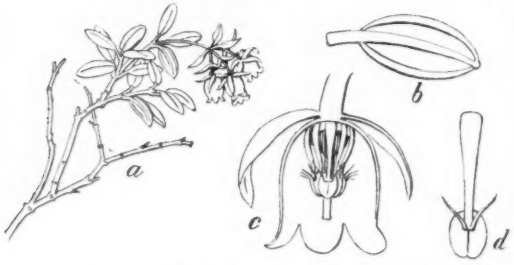

FIG. 1.—*Arcterica oxycoccoides* (Gray) Coville. *a*, the type specimen, natural size; *b*, leaf from beneath (× 3); *c*, flower, with part of calyx and corolla cut away (× 5); *d*, stamen (× 10).

Inflorescence a terminal cluster of three flowers, the peduncle 6^{mm} long and bearing at its summit a whorl of three purplish bracts, these about 4^{mm} long, the lower half conduplicate, the upper half expanding into an ovate-triangular blade; pedicels about 3^{mm} long with two opposite bracts near the middle, similar in size and appearance to the sepals.

Flower pentamerous. Calyx made up of lanceolate-oblong, purplish, acute sepals, pubescent at the apex on the margins and upper surface. Corolla cylindrical-urceolate, longer than broad, apparently white, about 4^{mm} in length, the rounded lobes about one-third the length of the tube. Ovary globose, the style cylindrical. Filaments larger toward the base, glabrous; anthers broadly oval to orbicular, biaristate near the base, the point of attachment to the filament, the dehiscence taking place through two apical pores facing the style.

The following generic characters, observed in the foliage and inflorescence, serve to distinguish Arcterica from Cassiope and Harrimanella:

CASSIOPE.	ARCTERICA.
Leaves opposite, cupressiform, imbricate, calcarate.	Leaves in whorls of three, chamaecistiform, with an apical gland.
Flowers axillary.	Flowers in terminal clusters.
Sepals with a transverse fold at the base.	Sepals not folded at base.
Anthers attached toward the apex.	Anthers attached by the base.

HARRIMANELLA.	ARCTERICA.
Leaves alternate, empetriform.	Leaves in whorls of three, chamaecistiform.
Flowers singly terminating the stems, not bracted.	Flowers in clusters, the pedicels subtended by a bract and bibracteolate at about the middle.
Style ovoid-conical.	Style cylindrical.
Anthers attached toward the apex.	Anthers attached by the base.

Illustrations of three species of Cassiope and two species of Harrimanella are given in the Washington Academy paper to which reference has already been made. In both Harrimanella and Cassiope the pollen pores, the two awns, and the point of attachment of the filament are close to the apex of the anther, but in Arcterica the filament and two awns are attached near the base of the anther, only the pollen pores being terminal. (*Fig. 2.*)

Superficially, in habit and foliage, Arcterica presents an appearance intermediate between *Chamaecistus procumbens* and *Vaccinium Vitis-Idaea*, but its leaves, situated in whorls of three, and its stamen characters suggest possible relationship to Erica. Apparently, however, it is not congeneric with any known species of that genus. Its corolla is not chartaceous; it is a depressed plant barely rising above the mosses and lichens among which it grows; its leaves have peculiar apical glands; and it is geographically isolated from the rest of the Ericae, none of which are known from either northeastern Asia or northwestern America. Whether the plant is more nearly related to Cassiope and Harrimanella, and belongs therefore to the tribe Andromedeae, or to Erica, of the tribe Ericeae, is a question likely to remain unanswered until fruiting specimens are available.

FIG. 2.—*a*, pistil and stamen of *Arcterica oxycoccoides*, showing attachment of awns and filament; *b*, the same organs in *Harrimanella stelleriana* (both × 5).

An attempt was made to explain the specimen on the ground that it was a hybrid, but there appear to be no two plants on Bering Island from which the characters found in Arcterica could be produced.—FREDERICK VERNON COVILLE, *Dept. of Agriculture, Washington, D. C.*

NEW PRECISION-APPLIANCES FOR USE IN PLANT PHYSIOLOGY.[1]

(WITH THREE FIGURES)

THE development of apparatus in this country for educational use in plant physiology has taken almost exclusively the direction of improvisation of the needful pieces from various existent physical, chemical, and mechanical articles, especially such as are very cheap and everywhere easy to obtain. In giving our inventions this turn it is evident that we have had in mind the needs of the smaller, poorer, and more backward institutions rather than the needs of the larger, richer, and more progressive; while, following the tendency usual in such cases, we have allowed ourselves to be carried to the extreme of reaction from the elaborate, costly, and mostly unpurchasable appliances previously used in this work. Improvisation has now, I believe, been carried to its utmost practical limit, and even to a greater extent than is educationally and scientifically desirable. Improvised apparatus certainly has its place and value, especially in that it permits the study of plant physiology in many places where otherwise it would be impossible, while its preparation cultivates a certain mechanical ingenuity and self-reliance. In general it is certainly true that such apparatus is vastly better than no apparatus. But it has also very great disadvantages, notably the waste of time commonly involved in its preparation and manipulation, in the inevitable inaccuracy of results, and above all in the wrong habit and erroneous ideal of scientific method inculcated by the use of such imperfect tools. Further, experience shows that the training in manipulation, while of value in itself, is gained at too great a cost of botanical training and knowledge; for usually the time and energy of the student are so fully absorbed in the preparation of the apparatus that he has little of either remaining for use in the study of the plants.

These facts, I believe, indicate that the next step needful in plant

[1] These appliances, with others to be described later, were exhibited and explained at the Philadelphia meeting of the Society for Plant Morphology and Physiology, December 30, 1903.

physiology is a movement to what may be called normal apparatus, viz., pieces manufactured especially for the particular purpose, yielding accurate quantitative results, capable of application to their work with convenience and economy of time, and purchasable from the stock of supply companies precisely as apparatus for physics and chemistry may be. With these ideas in mind I have been trying for some two years past to develop such pieces of normal apparatus for all of the principal physiological processes, and some of the results are described below, while descriptions of others are to follow later. I have had in mind primarily their educational use, but they should also be available for investigation, especially the investigation of those physiological life-histories of plants which will form a leading feature of the ecology of the near future. In their construction, scientific efficiency (involving accurate mechanical workmanship), has been the first consideration, practical convenience and economy in manipulation the second, availability for purchase by all who have the means and wish to buy them the third, while the matter of cost has come last. I have confidence that a people so devoted to efficiency, and so wealthy, as the Americans, will ultimately not begrudge the cost of really good educational appliances, though I expect that their introduction will be very slow. In order to make them generally available I have arranged for their manufacture and sale by the Bausch & Lomb Optical Co., of Rochester, N. Y., who will presently be prepared to supply them along with other articles, chemicals, etc., needed for work in plant physiology.

The reader interested in these matters will note that this is not the first attempt to provide such apparatus. Professor J. C. Arthur, of Purdue University, some years ago offered for sale several excellent pieces designed by himself, though apparently he has not continued their development. The field is open to all, and from the many pieces likely to be offered in the near future it is probable that the survival of the fittest will provide us with physiological apparatus of great exactness and convenience and of moderate cost.

I. CLINOSTAT.

The most essential single piece of apparatus in the laboratory of plant physiology is a clinostat. Several forms have been invented, of which the best known are the Pfeffer-Albrecht, the Wortmann, and the Hansen, all of German make and more or less costly and difficult to obtain, while several home-made forms have been described by American botanists.

My instrument is illustrated in the three accompanying figures. It consists essentially of the works of a powerful American eight-day clock, geared to a revolution in fifteen minutes, inclosed in a practically dust- and moisture-tight metal case, capable of being used in any desired position. Used vertically (*fig. 1*) it stands upon three leveling-legs and carries a disk with a rim holding a 4-inch pot saucer (to take up leakage from the pot), in which may be set any size of pot up to 5-inch, though in this position it will carry a still heavier pot. In this figure may also be seen, on the left of the spindle, the nut by which the works are started or stopped, and the covers of the winding-holes. It can, of course, be wound without disturbing the plant. Used horizontally (*fig. 2*) it may, by means of the perforated screw posts and clamping-screws on the back of the case, be fixed at any desired height on the vertical rod of any common laboratory support. The spindle rod, either carrying a plant attached by

FIG. 1.

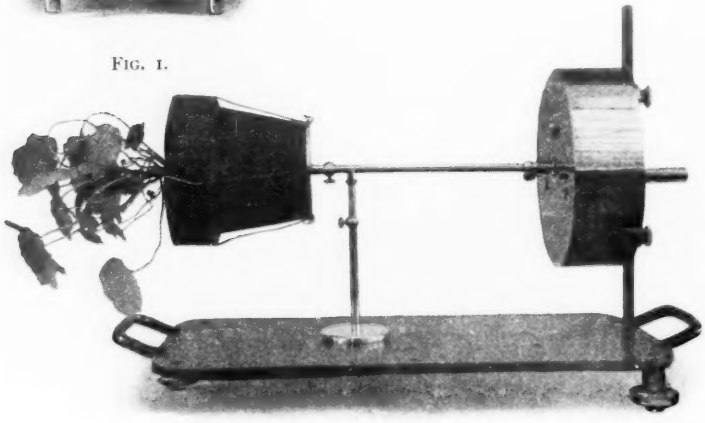

FIG. 2.

copper wire[4] to the perforated disk, as shown in the figure, or else carrying a pot, a peat-block, or a cork into a moist chamber, is supported near its distal end by a simple Y-support adjustable for height. In this position the instrument carries perfectly a 4- or 5-inch pot, and presumably a heavier one if well centered. Clamped upon a horizontal rod (*fig. 3*) it may also be used at any angle whatsoever, including complete inversion, the latter feature being, I believe, possible with none of the other obtainable forms.

FIG. 3.

Its special merits are its length of action (two days with one winding), entire efficiency in any position, compactness (whereby it may readily be placed under bell-jars, etc.), and moderate cost. Its demerits are its inability to carry plants of over 4- or 5-inch pot (though it is extremely rarely, and in educational demonstration never, the case that heavier plants are used), its single speed (though other speeds are extremely rarely, and in educational demonstration work never, needed), and its audible tick, which however is of a brisk and cheery character, quite in place in a laboratory.

II. PORTABLE CLAMP-STAND.

For many purposes in experimental plant physiology some form of clamp-stand, to support apparatus in special positions, is necessary, and one of the forms used in chemistry is generally adopted. For the

[4] So in the figure, but the completed instrument is to have screw rods instead of the wire.

simpler uses, these answer perfectly; but when several pieces must be supported near together, and when some articles must be set level, and especially where the whole must be removed from greenhouse or wardian case to lecture or laboratory table, it is necessary to improvise some form of tray or other support to carry the stands, with a device for leveling by wedges, etc. The new portable clamp-stand illustrated in *fig. 2* is intended to meet all of these needs in a single instrument. It is made of thin cast steel, reinforced underneath on the margin and at the holes, and is some 40×22^{cm} in size. It is perfectly plain on top, is provided with convenient handles, rests upon three legs in which leveling-screws are set, and is pierced by holes for the upright rods at points where experience and experiment show these to be most needed. The rods are of the size and thread usual in chemical supports, two in number, one 50 and one 25^{cm} long, though of course others can be added. The clamps, not shown in the figure, but to be illustrated in a figure to follow, are of a new form, light, strong, and firm, and are adjustable at any angle or in any plane.—W. F. GANONG, *Northampton, Mass.*

(*To be continued.*)

CURRENT LITERATURE.

BOOK REVIEWS.

The desert botanical laboratory.

A REPORT upon the Desert Botanical Laboratory established by the Carnegie Institution merits much more than a passing notice. This report, prepared by Messrs. Coville and MacDougal,[1] is admirably designed to set forth the important field which the Desert Laboratory is certain to occupy in

FIG. 1.—The Desert Botanical Laboratory of the Carnegie Institution at Tucson, Arizona.

research. Coville's botanical exploration of Death Valley, more than a decade ago, led him to hope that it would be possible to carry on systematic botanical observations in some American desert under the auspices of an institution such as the one which has just been established. It was wise on the part of the Carnegie Institution to entrust the important matter of the

[1] COVILLE, F. V., and MACDOUGAL, D. T.: Desert botanical laboratory of the Carnegie Institution. Imp. 8vo. pp. vi + 58. *pls. 29. figs. 4.* Washington: The Carnegie Institution. November 1903.

FIG. 2.—View westward from the laboratory. In the middle distance a strictly desert vegetation, consisting of giant cactus, palo verde, ocotillo, creosote bush, prickly pears, chollas, etc.

choice of a suitable location for the laboratory to the two men who know so well the ecological and other features of our deserts.

The report of this advisory board embraces an account of the journey along the Mexican border in search of a suitable site. There are twenty-nine fine photographic reproductions of typical desert landscapes, representing not only the features of the vegetation about Tucson, but also the more interesting ecological characteristics of the other deserts, which were visited, viz., the Tularosa desert of New Mexico, with its unique gypsum sand dunes; the deserts in the neighborhood of Torres and Guaymas, Mexico; the Colorado desert about Salton, Cal.; and the Grand Cañon of the Colorado in Arizona. In deciding upon Tucson for a laboratory site, regard was had for four requirements which an ideal site should possess: a distinct desert climate and flora, a flora that is rich and varied, accessibility, and habitability. In addition to these advantages, Tucson is the seat of the state university and agricultural experiment station, and its citizens cooperated enthusiastically in the enterprise—a matter of no small moment.

The chapter on the plant life of American deserts is introduced by a consideration of their meteorological and soil features; the most interesting table here is the one which gives the ratio between precipitation and evaporation. Instructive maps and soil analyses also illuminate this section. MacDougal's experiments on transpiration and temperature, which were conducted in the Arizona deserts near Flagstaff in 1898, are also included, and suggest one of the fruitful lines of investigation which the new laboratory will make possible.

The report concludes with an excellent bibliography of desert literature, prepared by the resident investigator, Dr. W. A. Cannon. The references are grouped under four heads: general treatises, references relating to climate, references relating to soil, and references relating to water. This bibliography will prove of immense assistance to investigators at the laboratory, and to students of similar problems everywhere.

While one cannot predict the exact place which the new laboratory is to occupy in botanical research, it is our right to expect great things, particularly in physiology and ecology, in which investigators are coming more and more to feel the need of field experiments. We may not hope to torture a desert plant into revealing its secrets to us in our laboratories and greenhouses, but it may unfold the mysteries of its life to those who live with it day by day in its own haunts. It is likely too that morphologists and taxonomists will find the Desert Laboratory of much help.— H. C. COWLES.

Plant chemistry.

"THIS BOOK"[2] is the outgrowth of instruction in chemistry given in the School of Agriculture of the University of Minnesota." It is intended for

[2] SNYDER, HARRY, The chemistry of plant and animal life. 12mo. pp. xvii + 406. New York City: The Macmillan Company. 1903. $1.40.

the use of students with no previous knowledge of chemistry. The first 154 pages are devoted to elementary chemistry. The headings of the remaining chapters will indicate the scope of the rest of the book. These are: the water-content and ash of plants; the non-nitrogenous organic compounds of plants; the nitrogenous organic compounds of plants; the chemistry of plant growth; composition of plants at different stages of growth; factors which influence the composition and feeding value of crops; composition of coarse fodders; wheat; maize; oats, etc.; mill- and by-products; roots, tubers, and fruits; fermentation; chemistry of digestion and nutrition; rational feeding of animals; composition of animal bodies; rational feeding of men. Interspersed throughout the book are directions for numerous simple experiments, designed to be performed by the pupil.

The chapters on pure chemistry deal only with the most important elements and compounds which enter into the composition of plants and animals. The treatment, in this part of the book, is very elementary, and often decidedly dogmatic. Some statements occur which are not free from serious objection. Thus on page 3: "It was believed, at one time, that metals, as copper, could be changed into gold, and other substances into different forms of matter. After many centuries of experimenting it was found that this could not be done, and as a result the law of the indestructibility of matter was established." The "change of substances into different forms of matter" is one of the principal subjects of the chemist's study. On the other hand, the question of transmutation has no bearing on the doctrine of the conservation of matter. On page 4 we find: "The reasons for accepting the molecular structure of matter cannot be profitably taken up by the student of elementary chemistry." And on page 13: "The way in which atomic weights are obtained cannot at this stage of the work, be profitably considered." The subject is not considered later; but, nevertheless, the terms "atom" and "molecule" are constantly employed, as are also chemical formulas, which are introduced on the twelfth page. It is to be feared that the student will gain the idea that atomic weights and formulas are obtained in some mysterious way, and that the properties of substances are to be deduced from these data by some sort of algebraic manipulation. Thus on page 73 it is stated: "In the study of acids, bases, and salts the character of the compound can always be determined from the formula, as $Ca(OH)_2$." The treatment of valence is equally objectionable. Under the heading "Impossible reactions," page 123, it is stated that in "the case of $BaSO_4 + 2HCl$ no reaction can take place," because these substances are the products of the action of $BaCl_2 + H_2SO_4$. This would seem to teach the impossibility of reversible reactions. Some statements are inaccurate. Thus, page 24: "Liquids are never weighed, but always measured;" page 40, "Hydrogen is liquefied with greater difficulty than any other element." This ignores helium. On page 58, speaking of water of crystallization, it is said: "Without this water crystals could not be formed." On page 113, benzene (C_6H_6) is referred to as

benzine and benzol; the term "benzine" is (correctly) used on page 110 to designate the petroleum product. On page 195 gum arabic and the gums of peach and cherry trees are mentioned as typical examples of gums. In the next line is the statement: "When treated with dilute acids the gums are converted into dextrose sugars and acid products." The gums mentioned as examples all give pentose sugars and not dextroses. Page 201: "Beeswax, for example, is composed of palmitic and ethyl radicals." The chief constituent of beeswax is myricyl palmitate, not ethyl palmitate. The whole of page 20 is devoted to description of plates I and II. On page 267 plate III is mentioned. There are no plates in the book. On page 406 there is a table of "Corrections;" but no such errors exist on the pages indicated.

In spite of some faults, there is a judicious selection of subjects, and in the applied part of the book a clear and concise treatment of the matter presented. While the book is not recommended as a text for elementary chemistry, the applied portions should prove very useful to students of agriculture, and interesting to all who, having an elementary knowledge of chemistry, are concerned in the subject of plant and animal nutrition.— H. N. McCoy.

The Bonn text-book.

THE FACT that this book,[3] addressed to college students, has reached its sixth edition in ten years is ample evidence of its popularity. One notices at once the name of Dr. G. Karsten instead of the late Dr. A. F. W. Schimper, who wrote the chapters on phanerogams for the previous editions. As before, the first three sections on morphology, physiology, and cryptogams, are treated by Strasburger, Noll, and Schenck respectively. In these three sections the sequence of topics and the method of treatment are practically the same as in the fifth edition, the principal revision appearing in the changes which have been necessary in order to keep the work fully abreast with recent contributions.

In the section on morphology the new figures and perhaps the most extensive revision of the text concerns the central cylinder of vascular plants. In the section on physiology the chapter on the "Stability of the plant body" has received a much more extended treatment than heretofore. More attention has also been given to ecology. In the cryptogams several new figures have been added, and slight changes, occasioned by recent studies, appear in the text.

In the treatment of the phanerogams one cannot speak of revision, for the entire section has been rewritten by Dr. G. Karsten. The gymnosperms receive more attention than previously. The arrangement of the angiosperms is practically that followed in Engler and Prantl's *Pflanzenfamilien*. By abbreviating the diagnoses of orders and families, Professor Karsten has

[3] STRASBURGER, E., NOLL, F., SCHENCK, H., and KARSTEN, G., Lehrbuch der Botanik für Hochschulen, 6th ed. Imp. 8vo. pp. viii + 591. *figs.* 741. Jena: Gustav Fischer. 1904. *M* 7.50.

made room for more interesting and important material. Particular attention is given to economic plants, especially those which have medicinal properties.

The number of illustrations has been increased from 686 to 741. Many of the old figures have been replaced by new ones, and the colored figures, which have always been a feature of the book, have been much improved by recent methods. Both authors and publishers deserve commendation for the frequent editions which have kept this work so thoroughly up to date.—C. J. CHAMBERLAIN.

Alpine vegetation.

ONE OF THE most valuable of tasks today is the compilation and systematization of scattered material. Such a labor has been performed by Marie Jerosch[4] in connection with the alpine vegetation of Switzerland. No claim to original work is put forth, although the critical study of 250 titles and the molding of discordant data into a harmonious whole are at least of equal value with most original investigations.

The work is essentially floristic rather than ecological. The first chapter deals with fundamental principles and motives, such as the origin of species, plant migrations, and polytopic appearance of species. The author is favorably inclined to all of the current evolutionary theories, and gives especial attention to Wettstein's seasonal dimorphism, and to mutation; the claim is made that Heer held a view essentially equivalent to mutation. The polytopic theory of Briquet is treated fully, but not very favorably. The second chapter considers the alpine and arctic climates from a comparative standpoint. The third and fourth chapters have to do with the Tertiary and Pleistocene history of the alpine regions. Then follows an account of postglacial changes, leading to a detailed consideration of the elements of the present alpine flora, together with their age and origin. Jerosch holds that an interglacial xerothermic or steppe period has been proved by the facts of plant geography, paleontology, and geology; there is more doubt as to a similar postglacial period.

There is no better illustration than that afforded by this book of the possibilities in floristic study. The glacial and postglacial floras of Switzerland and Scandinavia with all their vicissitudes are known almost as accurately as the floras actually in existence today. The fact that almost nothing is known of the glacial and early postglacial vegetation of America ought to stimulate many to study in this important and productive field.—H. C. COWLES.

Ecology of the Lena valley.

CAJANDER has given an excellent account of the vegetation of the alluvium of the lower Lena[5], in which particular attention is paid to the genetic

[4] JEROSCH, MARIE, Geschichte und Kerknuft der schweizerischen Alpenflora. Leipzig: Wilhelm Engelmann. 1903. *M* 8.

[5] CAJANDER, A. K., Die Alluvionen des unteren Lena-Thales. Helsingfors. 1903.

relations of the plant associations. The headwaters of the Lena are in the steppe and the mouth is in the tundra, but most of the stream traverses a forest region. While larch, spruce, and pine dominate southward, the forests nearer the mouth are composed almost wholly of larch. Alluvial savannas decrease northward. Cajander employs "Bestand" in the ordinary sense, but uses "association" where most authors use "formation." "Series" is used for a group of genetically connected associations. The forest associations usually start with a thicket of *Salix viminalis*, which is succeeded by a mixed thicket, and later in turn by alders, birch, and spruce. The final stage on areas subject to overflow is a forest of spruce and larch; on alluvium above the freshet line there are pure larch forests. Various succession series are found in the meadows, differences being largely due to variations in the character of the soil; the final stages are very similar. An interesting variation in the succession series is shown by *Equisetum arvense* which precedes *Carex acuta* in rich soil, but comes after it in pure sand. In his concluding remarks, Cajander introduces the term "vicarious associations," by which he means associations that occupy similar places in the genetic series. Associations are climatically vicarious if they occur in different regions; *e.g.*, the *Carex acuta* association replaces northward the *Carex aquatilis* association of the upper Lena. One may cite as an illustration of edaphically vicarious associations the *Equisetum fluviatile* and Eleocharis associations which occupy a pioneer position in different soils of the same region. — H. C. Cowles.

A flora of northwest America.[6]

Thomas Howell, so long known as an indefatigable collector, has brought together the results of years of field experience in a large volume describing the flowering plants of Oregon, Washington, and Idaho, a corner of the United States that had been left unprovided with a handy manual. Aside from the need of a manual for this region, the flora is one of the most interesting within our boundaries. The first fascicle of the present work was issued in 1897, although we are informed that the actual writing of the flora began in 1882, and now the completed seven fascicles appear in the volume before us. The sequence is that of Bentham and Hooker, the nomenclature is conservative, and the conception of species has been held to the old lines. Of the 3,150 species and varieties described 89 are new, but Mr. Howell is further to be credited with having contributed to monographers many more new species of his collecting.

This volume has been published under such unusual conditions, which are nowhere referred to in it, that they should be recorded. In 1896, when the first fascicle was ready for the printer, no typesetter able to set the tech-

[6] Howell, Thomas, A flora of northwest America, containing brief descriptions of all the known indigenous and naturalized plants growing without cultivation north of California, west of Utah, and south of British Columbia. Vol. I. Phanerogamae. 8vo pp. 816. 1903. Portland, Oregon: The author. $5.00.

nical matter could be found in Oregon. Accordingly the author learned to set type, and for nearly eight years has "set up" form after form until the 800 pages and more have been printed. We venture the assertion that no manual of botany, and probably no botanical work, has ever been issued at such a cost of labor to the author.

The value of the book is just what the experience of the author has made it, and no one knows so well the plants of the region covered. In addition to this, Mr. Howell is to be congratulated upon his indomitable pluck, in the presence of which a few typographical errors here and there and a little lack of typographical finish must be entirely forgotten.—J. M. C.

A study in heredity.

A STUDY in heredity by W. Johannsen[7] reaches the conclusion that Galton's law of regression is true in populations made up of several pure lines, but is not true in the pure lines taken singly. By a pure line is meant a group of individuals which have descended from a single self-fertilized individual. The author shows that a monomodal curve is not sufficient evidence that a population is homogeneous, but that a process of biological analysis must precede the general mathematical analysis, to attain satisfactory results. When Galton's law is found to hold in self-fertilizing populations it is interpreted as the result of incomplete isolation of the pure lines, and when the isolation is complete, *i. e.*, in a single pure line, there is complete regression of the mean characters of the offspring to the type of that line. This absolute fixity of type is too unique to be accepted without question, but if sustained by further research is a sufficiently important principle in questions of evolution in those special cases in which pure lines are involved, as in cleistogamous and other self-fertilizing populations, and in populations arising through parthenogenetic and vegetative reproduction. But exception may be taken to the author's view that the principle is fundamental to all study of heredity.

The results are based upon weight and form of seeds of *Phaseolus vulgaris* and on certain abnormalities in heads of rye. Only three generations are involved, and no account is taken of the influence of climatic fluctuations.—G. H. SHULL.

MINOR NOTICES.

THE VERMONT Agricultural Experiment Station has issued a bulletin dealing with the flow of maple sap.[8] The bulletin sets forth an enormous amount of experimental work, a large portion of which is directed to the physiological problems of sap pressure and sap flow. The effects of external

[7] JOHANNSEN, W., Ueber Erblichkeit in Populationen und in reinen Linien. pp. 68. *figs. 8.* Jena: Gustav Fischer. 1903.

[8] JONES, C. G., EDSON, A. W., and MORSE, W. J., The maple sap flow. Bull. 103, Vermont Agric. Expr. Sta. pp. 43–184. *figs. 6. pls. 17.* 1903.

conditions (temperature, light, etc.) and the location of the sap stream were extensively studied, though not always in the light of physiological knowledge already available. It seems clear from the results that both gas pressure due to rising temperature and osmotic pressure in living cells cause sap to flow from the tap holes, but it is obvious that the latter agency is much more important than has hitherto been believed. The practical problems of the sugar orchard have also been considered, and the results of the experimental work regarding them certainly furnish a basis for better practice than has obtained hitherto.—C. R. B.

T. A. BONSER has given a detailed account of Big Spring Prairie, Ohio, involving the results of several years of careful study.[9] The place is of much interest, since it represents a type of the edaphic prairies of the east. The study was also peculiarly timely in view of the artificial changes which the place is now undergoing. The prairie, like most edaphic prairies, represents a former lake bed. The author thinks that the general absence of trees is due to the dense sod, which precludes germination. That trees and shrubs thrive in the prairie is shown in burns and other modified places, where a foothold is given. The order of encroachment of trees in such places as well as on ridges of sand, clay, and rock, was studied and reported in detail. A matter of floristic interest is that this prairie is the most southern known habitat of *Betula pumila* in Ohio.—H. C. COWLES.

THE NEW YORK Forest, Fish, and Game Commission has recently issued a valuable publication on tree planting on streets and highways.[10] Among the subjects discussed are: the selection of trees, street planting, pruning, protection from insects, autumn foliage, municipal control, and the legislation of several states in regard to tree planting. The improvement of highways in the country and of property in the city by tree planting is forcefully presented. In regard to the latter the author says the planting and care of trees belongs to the city government as much as street paving. The work contains many excellent illustrations of the beautifying of streets by tree planting; also numerous plates showing the natural coloration of autumn leaves.—C. D. HOWE.

THE CHIEF interest in a paper by Émile Boulanger on the mycelium of the truffle lies in his claim that it is composed of polyhedric cells, and that several Hyphomycetes are conidial forms of the truffle![11]—H. HASSELBRING.

[9] BONSER, T. A., Ecological study of Big Spring prairie, Wyandot county, Ohio. Ohio Acad. Sci. Special paper no. 7. pp. 96. Columbus. 1903.

[10] FOX, W. F., Tree planting on streets and highways. Imp. 8vo. pp. 50. pls. 21. Albany: J. B. Lyon Co. 1903.

[11] BOULANGER, E., Les mycelium truffiers blancs; and Germination de l'ascospore de la truffe. pp. 20 and 23. *pls.* 5. Rennes, Paris: Published by the author. 1903.

NOTES FOR STUDENTS.

THE MUCH-STUDIED glandular hairs of *Dipsacus sylvestris* have been again examined by Rostock,[12] who finds no absorption of food materials, as F. Darwin suggested, and no absorption of the water itself, which is purely a protection to the leaves against snails and caterpillars.—C. R. B.

A SOMEWHAT EXHAUSTIVE STUDY of *Fegatella conica*, by F. Cavers[13] seems to indicate that in large measure it repeats the well-known history of Marchantia. Contrasting features are the simple air pores, the more differentiated thallus, the "mycorhizal zone," the larger sperms, and the fact that the cover-cell of the archegonium does not contribute to its elongation (which may be true also of Marchantia).—J. M. C.

RICHARDS AND MACDOUGAL[14] find that when the nitrogen of the air is replaced by CO or by illuminating gas, which contains *ca.* 40 per cent. of CO, seed plants of various kinds show toxic effects, growth, irritability, and chlorophyll formation being notably retarded or inhibited. Mosses were less affected, some enduring CO or "gas" for three months, with injury only to older leaves. In "gas" there are evidently present other toxic agents than CO.—C. R. B.

TONDERA finds[15] in the young internodes of the Cucurbitaceae the "starch-sheath" supplied with fine-grained starch, equally distributed through the protoplasm; whereas only in the older internodes which are not geotropic are there coarse grains that lie on the lower side of the cell. This, he argues, militates against the statolith theory of geotropism. He thinks the "starch-sheath" a storage region during the formation of the zone of mechanical tissue (stereome or collenchyma) which adjoins it.—C. R. B.

RAUNKIÆR[16] has arranged the species of Potamogeton into groups based mainly upon anatomical characters, such as the build of the central cylinder, presence or absence of cortical strands, nature of the endodermis. The author considers that anatomical distinctions are more satisfactory than any others in recognizing the different species. He claims to settle on anatomical grounds the vexed question as to what constitutes *P. fluitans* Roth, and concludes that two quite different plants have been included under this name.—M. A. CHRYSLER.

[12] ROSTOCK, R., Ueber die biologische Bedeutung der Drüsenhaare von *Dipsacus sylvestris*. Bot. Zeitung **62**[1]: 11–20. 1904.

[13] CAVERS, F., On the structure and biology of *Fegatella conica*. Ann. Botany **18**: 87–120. *pls. 6–7*. 1904.

[14] RICHARDS, H. M., and MACDOUGAL, D. T., The influence of carbon monoxid and other gases upon plants. Bull. Torr. Bot. Club **31**: 57–66. 1904.

[15] TONDERA, F., Contribution à la connaissance de la gaine d'amidon. Bull. Acad. Sci. Cracovie, Math. Nat. Cl. **1903**: 512–516. *pl. 1*.

[16] RAUNKIÆR, C., Anatomical Potamogeton-studies and *Potamogeton fluitans*. Botanisk Tidsskrift **25**: 253-280. 1903.

W. C. WORSDELL[17] has published a valuable historical sketch of the views that have been held as to the nature of the ovule. It is a great convenience to have the extensive literature of the subject digested and available in compact form. The views of the numerous contributors to the literature of the subject are put under three categories: (1) axial theory; (2) foliar theory; and (3) *sui generis* theory, which means that the ovule is to be regarded as an independent structure, borne either on stem or foliar organs. The bibliography contains 149 titles under 82 authors.— J. M. C.

KARSTEN AND SCHENCK have issued three more numbers of their valuable *Vegetationsbilder*.[18] The sixth number was prepared by Karsten and portrays the following tree monocotyledons: Pandanus, Zanthorraea, Yucca, Nolina, Dendrocalamus, Ravenala. In the seventh number Schenck illustrates the strand vegetation of Brazil, giving several photographs of the Pes-Caprae and Restinga formations. Karsten and Stahl prepared the eighth number, which treats of Mexican xerophytes. Excellent illustrations of cacti, agaves, and other desert forms are brought together. These numbers maintain the high standard of the earlier parts, and it is more apparent than ever that this publication is of great practical value to all botanical libraries and laboratories.— H. C. COWLES.

ERWIN F. SMITH AND DEANE B. SWINGLE[19] have published the results of their study of the dry rot of potatoes. The "bundle blackening" and "dry end-rot" are found to be two stages of the same disease, which begins in the field in the underground stems and roots. A fungus, which has proved to be a Fusarium, is always present in the darkened vascular bundles of the tubers. The fungus tolerates large amounts of certain acids, as malic, citric, and tartaric, and is inhibited by small amounts of others, as formic, acetic, and butyric. It attacks the plants from the soil and winters over in the earth, so that in land frequently planted to potatoes it can probably maintain itself indefinitely. Infected land should be planted to other crops for a series of years, and great care should be taken to avoid the infection of healthy land by planting diseased tubers.— J. M. C.

MOLISCH, seeking to check Friedel's and Macchiati's results, which indicate that photosynthesis is an enzymatic process,[20] reports experiments upon several plants, using the luminosity of *Micrococcus phosphoreus* as a reaction for the evolution of oxygen (Beijerinck's method, the sensitiveness of which

[17] WORSDELL, W. G., The structure and morphology of the "ovule." Ann. Botany **18**: 57–86. 1904.

[18] KARSTEN, G., and SCHENCK, H., Vegetationsbilder. Hefte 6, 7, 8. *pls. 31–48*. Jena: Gustav Fischer. 1903. Single parts *M* 4; to subscribers *M* 2.50.

[19] SMITH, ERWIN F., and SWINGLE, DEANE B., The dry rot of potato due to *Fusarium oxysporum*. U. S. Dept. Agric., Bur. Pl. Industry, Bull. 55. pp. 64. *pls. 8*. Issued Feb. 16, 1904.

[20] Reviewed in BOT. GAZ. **32**: 430. 1901; **33**: 315. 1902; **35**: 226. 1903.

he tested and confirmed).[21] Green sap, obtained by rubbing up fresh leaves in a mortar or by compression and filtering through paper, can set free oxygen. Leaves of *Lamium album* dried at room temperatures or in an oven at 35° C., so that they felt quite dry and had completely lost their vitality, were rubbed up with water and yielded a sap of like powers. But this, as shown by microscopic observation, was dependent upon the plasma particles and chloroplasts which pass through filter paper; for the same sap after filtration through a Berkefeld or Chamberland tube, whether from living or dead leaves, had no such reducing power. Molisch also attempted to repeat Friedel's and Macchiati's experiments, but unsuccessfully. His results with Lamium, however, incline him to think that it may yet be possible to study photosynthesis apart from the living cell.—C. R. B.

THE SUBJECT which Professor Seward[22] treats in a general way in his presidential address at the Southport meeting of the British Association is one of commanding importance to all students of plant evolution and geographical distribution, and yet it is a branch of the science much neglected by the students of modern groups. Professor Seward divides the world into twenty-two entirely arbitrary regions, and discusses briefly the rise and fall of the various botanical types that have moved across the stage from the pre-Devonian to the present time. It would seem to the writer that the differences between the northern and southern floras in the Carboniferous are emphasized somewhat more strongly than the evidence warrants, and that Professor Seward unduly depreciates paleobotanical evidence other than what is based on anatomical studies of tissues and fructifications. While it is unfortunately true that the latter Mesozoic formations furnish us with almost nothing but carbonaceous impressions, and while we might wish it otherwise, still we cannot afford to ignore what facts we have of the days when the angiosperms were rapidly assuming the leading rôle in the vegetation of the world. The whole address is a most able and earnest plea for a sympathetic study of ancient floras and for a wider viewpoint among specialists in that field of botanical activity. It is eminently desirable that it should receive more attention from American botanists than it is likely to attract.—EDWARD W. BERRY.

PALEOBOTANICAL NOTES.—KATZER,[23] in a short paper on the geological development of the *Braunkohlenschichte* of the Zenicer depression in Bosnia, enumerates fourteen well-known species of Miocene plants. This

[21] MOLISCH, H., Ueber Kohlensäure-Versuche mittelst der Leuchtbacterienmethode. Bot. Zeitung **62**[1]: 1–10. 1904.

[22] SEWARD, A. C., Floras of the past: their composition and distribution, British Assn. Adv. Sci. Southport. 1903.

[23] KATZER, F., Geološki razvoj naslage mrkog nglja n zeničkoj kotlini. (Geol. Entwickelung der Braunkohlenschichte der Zenicker Depression) Glasnik gemalj. muz. n Bosni i Hercegov. **15**: 101. 1903.

paper is followed by a more lengthy paper by Engelhardt,[24] who enumerates sixty-two species of plants from this region in Bosnia in beds of the Miocene age. Two species of *Tilia* from Doboj and Kakanj are described as new. The flora shows a considerable mixture of northern and southern forms, and includes twenty-six species common to the American Tertiary.—KIDSON[25] has described the Carboniferous plant remains from the border region of Canobie and Dumfriesshire, Scotland, and parts of Cumberland and Northumberland, England. They include remains from both the lower barren measures and from the upper measures, some of the horizons of the latter not before known in this region. A new genus, *Eskdalia*, is proposed for the reception of certain fern stems, and a number of new species in other genera are described.—ARBER and NEWELL[26] have a paper on homoeomorphy among fossil plants illustrating that well-known tendency exhibited in some groups of unallied forms to show an aggregate of common characters. While the term is not exactly synonymous with what has been called convergence, it seems to be the same as the term "homoplasy" as used by the zoölogists Lankester and Osborn, or the "homomorphy" of Fürbringer. POOLE[27] contributes a short paper on a remarkably well-preserved section of Stigmaria from the coal measures of Stellarton. The scalariform tissue of the medulla is particularly well shown. There are over thirty vascular bundles, each containing from five to fifteen radial rows of rectangular cells, with about forty cells in each row.—Contributions of minor importance are an anatomical paper by STOPES[28] on the epidermoidal layer of calamite roots; a paper on *Xenophyton radiculosum* and on a stigmarian rootlet probably related to *Lepidophloiois fuliginosus*, by WEISS;[29] a paper by KERNER[30] describing a new locality for Tertiary plants in Dalmatia; a paper by KIDSON[31] entitled Notes on some Scottish floras of Lower Carboniferousage; and a paper by STERZEL[32] on the character of the floras of the Carboniferous and Permian from the well-known locality of Zwickau in Saxony.—EDWARD W. BERRY.

[24] ENGELHARDT, H., Prilog poznavanjn fosilne flore is naslage smegjeg ngljena n kotlini Zenica-Sarajevo n Bosni. (Beitr. z. Kennt. der foss. Fl. aus der Braunkohlenschichte im Sarajevo, Zenicer, Kassel in Bosnien) *Ibid.* **15**: 115–136. 1903.

[25] KIDSON, R., The fossil plants of the Carboniferous rocks of Canonbie, etc. Trans. Roy. Soc. Edinburgh **40**: 741–833. *pl. 1–5* and *fig. in text.* 1903.

[26] ARBER and NEWELL, Geol. Mag. N. S. **10**: 388–395. Sept. 1903.

[27] POOLE, H. S., Proc. & Trans. Nova Scotia Inst. Sci. **10**[3]: 345–347. *pl. 2.* Oct. 1902.

[28] STOPES, M. C., Ann. Botany 792–794. 1903.

[29] WEISS, F. E., Mem. & Proc. Manch. Lit. & Philos. Soc. **46**: pt. 3. 1902.

[30] KERNER, F., Verh. k.k. Reichsanstalt **1903**: 342–344.

[31] KIDSON, R., Summary of Prog. Geol. Surv. United Kingdom for 1903. pp. 130–137.

[32] STERZEL, T., Erl. geol. Specialkarte Königr. Sachsen. 2 Aufl. Leipzig 1901. pp. 85–139.

VERNON H. BLACKMAN[33] has published a preliminary notice of the results of his study of the Uredineae, the full paper, with figures, to appear later in the Annals of Botany. The forms studied were *Phragmidium violaceum* Wint. and *Gymnosporangium clavariaeforme* Rees. Sapin-Trouffy's cycle of nuclear development was confirmed, which is as follows: the mature teleutospore is uninucleate and this condition persists through sporidia and the aecidial mycelium; in the young aecidium the nuclei become paired, and this condition persists through aecidiospores, the ensuing mycelium, the uredospores, and into the young teleutospores; in the maturing teleutospores the two nuclei fuse. It was this fusion in the teleutospore that Sapin-Trouffy regarded as fertilization.

Blackman concludes that the spermatia are male cells that have become functionless, basing his conclusions upon the cytological characters, which are clearly those of male cells and not of conidia. The aecidium of *P. violaceum* arises as a layer of rectangular uninucleate cells just beneath the epidermis of the leaf. Each of these cells becomes divided into a short sterile cell above, which soon degenerates, and a fertile cell below, which becomes binucleate and gives origin to a row of binucleate aecidiospore mother-cells. Thus the condition of paired nuclei starts in the fertile cell and is continued to the teleutospore. The fertile cell, which the author regards as a female cell, does not become binucleate by division of its original single nucleus, but by the migration through the walls of the nucleus of a neighboring vegetative cell. This association of the two nuclei he regards as representing fertilization, rather than the act of fusion in the teleutospore.

This means a sharply marked alternation of generations among the Uredineae. The gametophyte starts with the uninucleate teleutospore, the production of the four sporidia representing a tetrad division; from these the mycelium of the gametophyte develops and produces later the spermogonia and aecidia. The fertilized cell in the aecidium starts the sporophyte generation with paired nuclei, from which the aecidiospores almost immediately arise; the sporophyte mycelium bears later uredospores and finally teleutospores. The fusion of nuclei in the teleutospore cannot then be looked upon as a process of fertilization, but merely as the secondary process which brings about the disappearance of the special cytological conditions initiated by fertilization, *i. e.*, change from the sporophytic to the gametophytic condition; it must accordingly be looked upon as a reduction process. Like the reduction process in higher plants, it is followed by a tetrad division. These conclusions apply also to the fusion of nuclei in the basidium, as Maire has shown that Basidiomycetes also have paired nuclei that fuse in the basidium.

Just how the fusion of sexual and vegetative nuclei is to be regarded as fertilization is not clear, but such cases loosen up the previous rigidity of

[33] BLACKMAN, VERNON H., On the fertilization, alternation of generations, and general cytology of the Uredineae. Preliminary notice. New Phytologist 3: 23–27. 1904.

ideas concerning fertilization. Farmer's phrase "apogamous fertilization" is a proper expression of uncertainty in reference to the definite criteria of fertilization. — J. M. C.

TWO PAPERS by Fitting constitute a very valuable contribution to our knowledge of the physiology of tendrils. The earlier paper[34] is a quantitative study of the growth of stimulated and unstimulated tendrils. Special attention is given to curvatures resulting from contact stimulus, but those resulting from amputation, temperature variation, and mechanical bending are also considered.

The growth of unstimulated tendrils is intercalary, being most intense in the basal half and manifesting two distinct phases of acceleration separated by a period of diminished rate. Growth is uniformly distributed in the tendrils in the first of these two phases, but in the second curvature appears as a consequence of unequally distributed growth, which is maximum at the periphery of the side becoming convex and gradually diminishes to zero at the periphery of the concave side.

Especially notable is the author's discovery of high perception capacity associated with low reaction capacity. It has long been known that some tendrils react to stimuli applied on any side and others only when stimulated on one side. The latter are, however, sensitive on all sides, even though unable to respond to stimuli not ventrally applied. This is shown when a stimulus dorsally applied inhibits response to one ventrally applied. In such tendrils a dorsal stimulus will even inhibit the completion of a curve already commenced in response to a ventral stimulus.

The stimulation of opposite sides does not appreciably affect growth in either uniformly reacting or locally reacting tendrils. The curvature formed in response to contact stimulus is after a period of hesitation followed by a reverse curve which accomplishes straightening and is regarded by Fitting as autotropic. The mechanism is the same in each of these curves, the growth of the middle zone being accelerated. This eliminates turgor variation as a factor in curvature, especially since the growth of the concave side is not actually retarded.

The correction of artificial bendings mechanically formed coincides in process with formation of curves in response to contact stimulus. Haptrotropic curvatures are distinguishable from other tropic curves by the manifest acceleration in growth of middle zone. The encircling of a support is accomplished by curves formed in response to a series of contact stimuli. Prolonged contact is not a stimulus to effect an acceleration of growth. Exception is taken to Noll's "Reizfelder" hypothesis.

The later paper[35] is a further study of the curves produced in tendrils as

[34] FITTING, HANS, Untersuchungen über den Haptrotropismus der Ranken. Jahrb. Wiss. Bot. **38**: 545–634. 1903.

[35] FITTING, H., Weitere Untersuchungen zur Physiologie der Ranken. *Ibid.* **39**: 424–526. 1903.

a result of decapitation and amputation, together with a consideration of the physiology of stimulus transmission in tendrils and in Mimosa.

When tendrils of *Passiflora* sp. are severed at the base, a strong apical curvature appears in one or two minutes. This curvature is limited to the haptrotropically sensitive zone and becomes corrected if the tendril has its cut surface in water. Both curvature and recurvature are true growth phenomena, being dependent upon an accelerated growth of the middle zone. Similar responses may be obtained with tendrils belonging to widely different families, although minor modifications appear. In some tendrils a fluid drop exudes from the exposed surface, and in others no such drop appears. The incision must enter the central cylinder in order to produce a curve. Piercing with a fine needle is a stimulus if the central cylinder is penetrated. The impulse travels from the locus of amputation toward the motor zone very rapidly, even as fast as 20^{mm} per second, and the actual rate is probably greater because the larger portion of time elapsing between stimulation and response is to be considered as a latent period.

From old and new experiments it is evident that the process of transmitting a wound stimulus in Mimosa coincides in all essential particulars with such a process in tendrils. All indications are that in Mimosa transmission occurs in the living cells. Since in some cases an impulse is carried beyond a deadened zone it seems improbable that the plasma actively participates in the transmission. Haberlandt's theory of a diminution of hydrostatic pressure in the conductive tissue as an explanation of the transmission process is inadequate because it occurs in plants which are without *Schlauchzellen*. — RAYMOND H. POND.

NEWS.

DR. D. H. SCOTT has been elected president of the Royal Microscopical Society for the ensuing year.

ÉMILE LAURENT, professor of botany in the State Agricultural Institute, Gembloux, Belgium, died *en route* from a fever contracted while recently visiting Sierre Leone.

PROFESSOR HUGO DE VRIES, of Amsterdam, will give a series of five lectures at the University of Chicago, August 22–26 next. He lectures earlier in the summer at the University of California, but we are not informed as to details.

WILLIAM M. CANBY, of Wilmington, Delaware, died on March 10 at Augusta, Georgia, while on a visit to the South for the benefit of his health. The name of Mr. Canby is a very familiar one to American taxonomists, and it stands to them not merely for one of our best-known older botanists, but for a friend who was always genial and helpful.

THE SESSION of the biological laboratory of the Brooklyn Institute for 1904 will be held at Cold Spring Harbor, beginning July 6 and continuing six weeks, under the general charge of Professor C. B. Davenport of the University of Chicago. Instruction in cryptogamic botany will be given by Professor D. S. Johnson and Mr. A. H. Chivers, and in plant ecology by Mr. Forrest Shreve.

DR. BURTON E. LIVINGSTON, of the University of Chicago, has received a grant from the Carnegie Institution to be used in an investigation of the relations which exist between soil properties and vegetational characteristics in the arid region of New Mexico, Arizona, and California. The work will be carried on during the coming summer, with headquarters at the Desert Botanical Laboratory at Tucson, Arizona.

THE SEASON of the Minnesota Seaside Station for 1904 begins about the middle of July and continues for six weeks. The botanical work will be under the general direction of Professor Conway MacMillan, who will conduct special laboratory courses upon the ecology and morphology of the kelps, and upon the anatomy and classification of the liverworts and mosses of the region. Miss Josephine E. Tilden will give courses upon algae, and Dr. Albert Schneider will offer work upon the lichens, and will also give lectures upon bacteria and nitrogen assimilation.

THE SEVENTEENTH session of the Marine Biological Laboratory at Woods Hole will begin June 1 and close October 1. The instruction in botany consists of a course on thallophytes from June 29 to August 10, which will be given

by Professor Davis (Chicago) who is in general charge of the botanical department, and Dr. Moore (U. S. Dept. Agric.). Other members of the staff, who may be consulted regarding research, are Messrs. True and Kearney (U. S. Dept. Agric.), Lyman (Dartmouth) and Wolfe (Harvard). The usual course of general lectures may be expected.

THE BERMUDA BIOLOGICAL STATION for research, at Flatts, Bermuda, will be open again for six weeks during the coming summer. The Station is under the direction of Professor E. L. Mark of Harvard University and Professor C. L. Bristol of New York University, and every opportunity will be given to those botanists and zoölogists who come to the station with definite problems. The date of sailing from New York is July 2, and the total expense of the six weeks, including transportation, board, and lodging, will be $100. Applications cannot be received later than May 1.

THE COMMITTEE in charge of the scientific congresses at the Louisiana Purchase Exposition have arranged for the presence of several distinguished foreign botanists, who will give addresses. Acceptances have been received from Professors K. GOEBEL of Munich; F. O. BOWER of Glasgow; J. WIESNER of Vienna; O. DRUDE of Dresden; CH. FLAHAULT of Montpellier. Dr. H. DE VRIES of Amsterdam has also been invited to give an address and it is probable that he will accept. The botanical congress begins Sept. 19. Announcement of American speakers and presiding officers will be made later.

THE PREPARATIONS for the second international botanical congress to be held at Vienna in June 1905 are progressing under the direction of various committees. Of course, as the nomenclature question is to occupy a prominent place in the deliberations, and as the proposals must be submitted far in advance of the meeting, it appears at this time as though nomenclature was the sole subject before the congress. But other parts of the program will be developed in due time. The general secretary of the international commission on nomenclature, John Briquet, has already received from Otto Kuntze a *Codex brevis maturus*, which the author desires to have solely control the organization of the congress and form the basis of its discussions! About this remarkable proposition there has been the usual vigorous and even vituperative correspondence, which has been disseminated by Dr. Kuntze. The motto of the Kuntze party has been well formulated by Dr. Ernst H. L. Krause, "Aut Kuntze aut nihil!" Twenty-three Swiss and Belgian botanists have also submitted proposals. The American committee on nomenclature recently held a meeting in Philadelphia and completed the formulation of its proposals, which will be submitted in due form before June 30. Doubtless there will be still others. We trust American botanists will not neglect to contribute to the proposed exposition, fully announced by the Association Internationale des Botanistes in the *Botanisches Centralblatt*.